SESSION 8C

WEED CONTROL IN FRUIT AND HARDY ORNAMENTAL NURSERY STOCK

SESSION ORGANISER MR G. C. WHITE

RESEARCH REPORTS (Poster papers) 8C-39 to 8C-48

A NOVEL MIXTURE OF GLYPHOSATE WITH SIMAZINE FOR THE CONTROL OF ANNUAL AND PERENNIAL WEEDS IN ORCHARDS

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SUMMARY

A formulated mixture of glyphosate and simazine has been developed to overcome the antagonism to glyphosate activity previously noted in tank mixtures.

Ten trials were carried out between 1983 and 1985 to investigate the foliar kill and residual activity of the mixture when used in the autumn or spring. Comparisons were made with common herbicide programmes. Excellent control of perennial and annual grasses was given by 4.56 kg ai/ha of glyphosate plus simazine as the formulated product, but good control of perennial broad-leaved weeds is dependent on correct timing of application. Residual control of annual weeds has been good except from those normally tolerant to simazine. No crop phytotoxicity was observed.

INTRODUCTION

This is a formulated mixture of glyphosate salt and simazine (100 + 280 g ai/l) for use in orchards and non-crop areas. In this paper it will be referred to as the glyphosate/simazine mix (380g ai/l). Both active ingredients are widely used in orchards and have complementary modes of action, being foliar and soil acting herbicides, respectively. The activity of the isopropylamine glyphosate salt is reduced when it is tank mixed with many soil acting herbicides (Baird et al 1971, Seddon 1974). This is probably caused by the formulation ingredients of the residual herbicides which may affect chemical bonding or have a physiological action, rather than absorbing the glyphosate (Turner, 1984). Currently growers are recommended to apply a sequential treatment but recently Rival herbicide has been formulated to minimise this antagonism.

The product has been tested extensively by Monsanto in Europe (David & Prevotat 1983 - Mattos Coelho, 1984), where it was launched in 1984 in France for use in vines. This paper reviews trials which were undertaken to confirm the activity of the product under UK conditions.

MATERIAL AND METHODS

Three small plot trials have been carried out to test a range of doses of the glyphosate/simazine mix against glyphosate alone and other standard orchard herbicides. These trials were sprayed using a Van der Weij sprayer at a volume of 400 l/ha.

A further seven grower-applied trials were undertaken in autumn 1984 and spring 1985, comparing the glyphosate simazine mix with the growers' standard. The growers were asked to follow the standard glyphosate timing restrictions in orchards applying the products after leaf-fall in the autumn and up to green cluster in the spring. The plots were oversprayed by the growers if they considered it necessary. The site and application details are summarised in Tables 1 and 2.

TABLE 1

Site Details.

Site	Location	Crop	Sprayer Type	Nozzle Type	Volume (l/ha)
1	Wisbech	Pear	small plot	flat fan	400
2	Cottenham	Pear	small plot	flat fan	400
3	Cottenham	Apple	small plot	flat fan	400
4.	Cottenham	Plum*	small plot	flat fan	400
5	Chelmsford	Apple	boom	anvil & flat fan	
6	Colchester	Apple	boom	anvil	370
7	Chelmsford	Pear/ Apple	boom	anvil & flat fan	500
8	Maidstone	Apple	boom	anvil	650
9	Sittingbourne	Apple	boom	flat fan	450
10	Herne Bay	Apple	knapsack	anvil	450
11	Chelmsford	Pear/ Apple	boom	anvil & flat fan	500

* Simazine based products are not recommended on stone fruit.

TABLE 2. Treatment details & dates of application

a) Small plot trials

	Site	Treatment (l/ha)						
			A		B	B * E	C * E	D * E
		10	12.5	15	4	4 * 6	4 * 6	22.5 * 4
1983	1	26/4	-	-	22/4	22/4 - 26/4	--	24/4 - 26/4
	2	10/5	-	-	27/4	27/4 - 10/5	27/4 - 10/5	---
	3	10/5	-	-	27/4	27/4 - 10/5	27/4 - 10/5	---
1984	4	11/5	11/5	11/5	-	11/5 - 21/5	11/5 - 21/5	---

b) Grower trials

		Experimental treatment (l/ha)	Grower standard (l/ha)
1984-5	5	10/5 A (4.56) * 23/5 D+E+I	12/11 D+E * 23/5 D+E+I
	6	12/11 A (4.56) * 17/6 F	1/2 E * 17/6 F
	7	26/11 A (4.56) * 17/4 F	4/6 F
1985	8	6/4 A (3.0,4.56) * 14/6 G	16/4 D+E+G
	9	26/4 A " " * 4/6 H	23/4 D+E * 4/6 H
	10	17/4 A " "	17/4 J
	11	16/4 A " " * 17/6 D+F	17/4 D+E+F * 17/7 F

Key to treatments: signifies sequential application

A glyphosate/simazine mix
B glyphosate
C paraquat
D amino triazole
E simazine
F dicamba/MCPA/mecoprop mix
G dichlorprop/mecoprop/MCPA/2, 4-D mix
H dicamba, 2, 4, 5-T, mecoprop mix
I pendimethalin
J paraquat/simazine mix

Detailed records were kept by the growers and visits were also made by Monsanto staff to assess percent weed control and crop phytotoxicity.

RESULTS

1. Speed of Action

Symptoms of glyphosate activity on emerged weeds appear most rapidly when their growth is most vigorous. The glyphosate/simazine mix at 4.56 kg ai/ha applied in the late autumn took nearly two months longer to give 90% foliar kill of *Elymus repens* than similar applications made in early spring (Fig.1). Control six months after both the treatments was similar. Activity against perennial broad-leaved weeds is slower than on grasses but the speed on both groups is similar to Roundup applied alone.

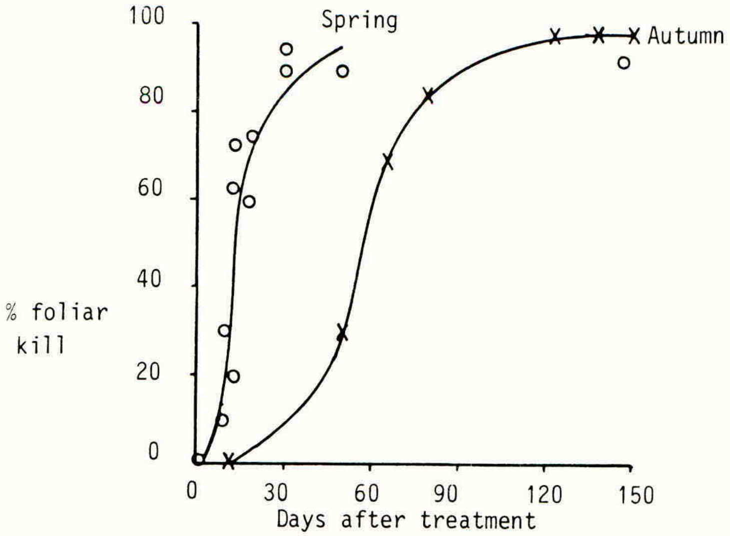

Fig. 1. Speed of action of the glyphosate/ simazine mix (4.56kg ai/ha) against the perennial grasses which occured in all trials.

Applications of the glyphosate/simazine mix at 3.8 kg ai/ha or glyphosate at 1.44 kg ai/ha in early spring (trials 1 - 3) gave poor control of perennial broad-leaved weeds, with almost complete regrowth one year after treatment. Applied later in the spring (trial 4) outside the timing recommendations, the results were improved on some species. A dose of 4.56 kg ai/ha maintained acceptable control of Calystegia sepium and Polygonum amphibium at 146 days after treatment (Fig 3). This was superior to glyphosate applied at a higher dose, 1.75 kg ai/ha, but the glyphosate/simazine mix gave poorer control of Urtica dioica and Cirsium arvense.

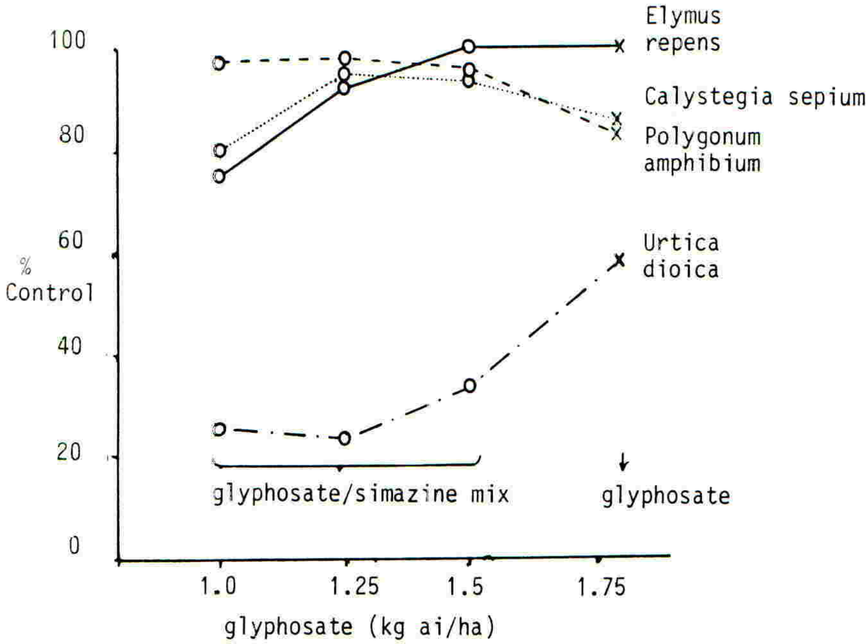

Fig. 3 Perennial weed control 146 days after treatment using the glyphosate/simazine mix or glyphosate above.

These results were confirmed by the grower trials (trial 5 - 11, Table 3). Although the timing of the sprays was unsuitable for optimum control of perennial broad-leaved weeds, at 4.56kg ai/ha, applications of the glyphosate/simazine mix to Cirsium arvense and Urtica dioica gave particularly poor results. There was a useful suppression of these species but the growers over-sprayed in all trials where they occurred. The only perennial broad-leaved species to be well controlled by 4.56kg ai/ha was Potentilla reptans which was a serious problem in one orchard. This species maintained green leaves through the autumn and was particularly well controlled by the Autumn treatment. Foliar kill of all these species by the growers' standard, aminotriazole, was slightly poorer for autumn treatments. The growers' spring standards were superior to the glyphosate/simazine mix, having been designed for their particular problems.

2. Control of Perennial Grasses

Most perennial grasses are very susceptible to the glyphosate/simazine mix at 4.56 kg ai/ha as they are to glyphosate applied alone (Figs 1 - 3, Table 3). Of those found in the trials, Agrostis stolonifera was the most susceptible species followed by Elymus repens, then Lolium perenne. These species were all acceptably controlled one year after treatment but although Festuca rubra was heavily suppressed by a December treatment, it regrew in the following summer. Most of these grass weeds maintain some green foliage through the winter, allowing adequate uptake of glyphosate.

Rate for rate of glyphosate, the addition of simazine to glyphosate in the formulated mix has little effect on year-long control of perennial grasses compared to glyphosate alone.

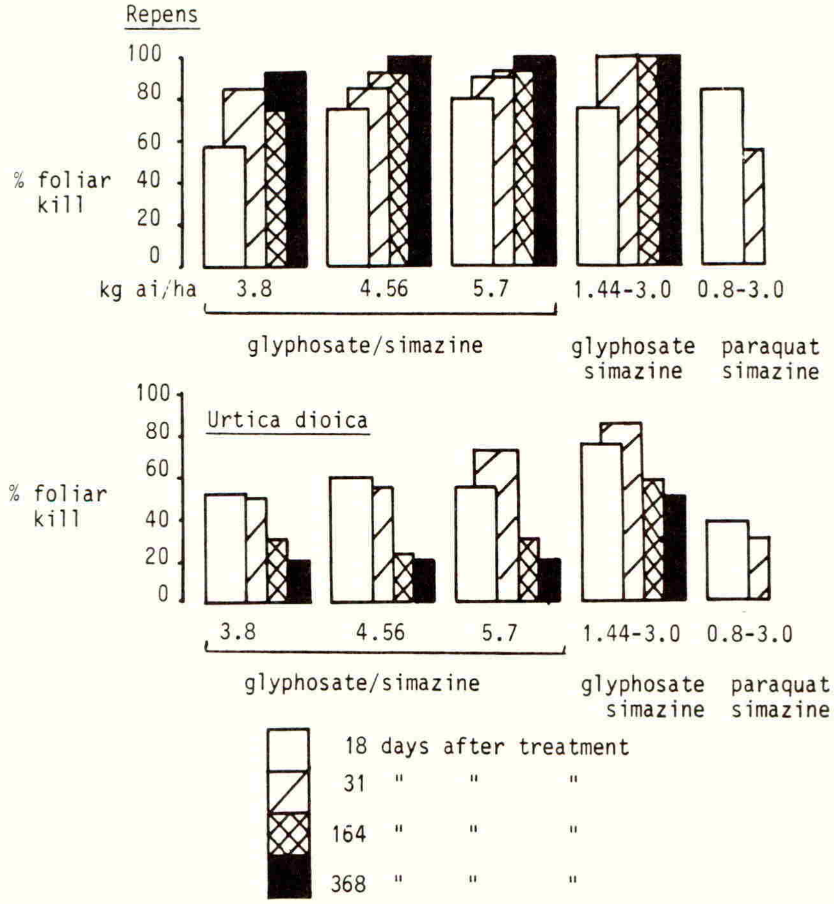

FIG. 2 Dose response for the glyphosate/simazine mix with time after treatment.

3. Control of Perennial Broad-leaved Weeds

Perennial broad-leaved weeds tend to die back more completely than grasses over winter and it is more difficult to spray at a suitable weed growth stage within the crop growth stages.

TABLE 3

Weed control with the glyphosate/simazine mix (4.56 kg ai/ha) 20 weeks after treatment

	Autum '84 No. sites	% control	Spring '85 application No. sites	% control
Species:				
Poa annua	3	99	2	75
Agrostis stolonifera	3	98	2	90
Elymus repens	-	-	1	80
Festuca rubra	1	90	-	-
Galium aparine	2	0	3	10
Polygonum aviculare	1	0	2	0
Seneci vulgaris	1	100	-	-
Stellaria media	1	100	1	90
Cirsium arvense	1	0	2	10
Convolvulus arvensis	-	-	3	0
Epilobium angustifolium	2	43	-	-
Epilobium adenocaulon	-	-	2	20
Heracleum sphondylum	-	-	1	30
Plantago major	1	75	2	60
Potentilla reptans	1	90	1	50
Ranunculus repens	1	40	2	20
Trifolium repens	1	80	-	-
Urtica dioica	-	-	2	20

4. Annual Weed Control

All species of emerged, actively growing annual weeds have been controlled acceptably by the glyphosate/simazine mix at as low as 3.04kg ai/ha. Control of weeds emerging after application has been more variable. Poa annua has germinated at the soil surface within 3 months of applying 3.04 or 4.56kg ai/ha. Polygonum aviculare and Galium aparine have proved particular problems since they are tolerant to simazine. The results have been similar to simazine applied alone at the equivalent dose alone or in sequence with glyphosate.

5. Crop Phytotoxicity

Crop damage has been noted at only one site, where the grower applied the product in an apple orchard with low branches which had not completely lost their leaves (Trial 6). The symptoms were similar to those described by Atkinson (1984). No damage was noted in the plum trial but the product will not be recommended in stone fruit due to their susceptibility to repeated simazine applications.

DISCUSSION

Trials 1 - 3 confirmed the antagonism of glyphosate caused by tank mixing with simazine (Baird et al 1971, Seddon 1974), although when formulated together the antagonism to perennial grasses was minimal. The major antagonistic effects were seen on perennial broad-leaved species. This problem might be overcome by raising the dose of the product but this could result in a very high dose of simazine and the difficulty in timing the application may still prevent optimum activity.

The sensitivity of the crop when it is in leaf is the major limitation to the use of glyphosate in orchards (Atkinson 1985). The weeds are most susceptible when the crop is most sensitive. Consequently, there is a limited time after leaf-fall in the autumn and a short period in spring up to green cluster when glyphosate can be applied to a reasonable growth of weeds. Unfortunately, many perennial broad-leaved weeds often have little green leaf area at these times, resulting in the poor weed control observed in the trials.

These narrow periods for glyphosate application are not ideal for simazine activity. Many growers spray simazine during February or early March when the soil is wet, ie at least two weeks before glyphosate should be applied. The simazine in the mix is applied later when soils are beginning to dry out, reducing the activity on emerging weeds.

In conclusion, the present formulation of glyphosate plus simazine gives the orchard grower the opportunity of combined control of emerged and emerging weeds over a spectrum of species broader than that of most other single products.

These results pertain to conditions in southern England and do not necessarily reflect results in other climates where the product has performed excellently.

ACKNOWLEDGEMENTS

Grateful thanks are due to the growers in whose orchards the trials were conducted.

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CONTROL OF ANNUAL AND PERENNIAL GRASSES WITH FLUAZIFOP-BUTYL IN CITRUS

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ABSTRACT

Single application of fluazifop-butyl at 0.5 and 1.0 kg/ha was evaluated to examine the degree and duration of the control of two annual and four perennial grass species. The grass species were: *Brachiaria mutica*, *B. pilligera*, *Cynodon dactylon*, *Panicum maximum*, *P. repens*, and *Paspalum notatum*. Higher rates provided higher and longer duration weed control than lower rates. Fluazifop-butyl was more effective in controlling annual grasses than perennial ones. *B. mutica* and *P. repens* were the most tolerant grasses and the regrowth started 42 days after treatment. Maximum control was recorded 42 days after treatment and thereafter regrowth started in most of the treatments. The results were consistent in both years.

INTRODUCTION

Citrus is grown in the subtropical climate of central Florida. Warmer temperatures throughout the year with rainfall ranging from 1200 to 1500 mm combined with high rate of nutrients provide an ideal environment for weed growth. Weeds compete with trees for nutrients in both young and old orchards but this effect is more pronounced on younger trees. Grasses pose a serious problem in younger trees since they can grow taller than the trees. Glyphosate and paraquat are the only post-emergence herbicides registered for the control of emerged grasses. Both of these herbicides are non-selective and are phytotoxic to citrus trees. Therefore, in a situation where grasses are growing too close to a tree, glyphosate and paraquat cannot be used without a risk. In our preliminary studies, we screened several selective post-emergence herbicides for the control of both annual and perennial grasses in citrus. The results indicated that fluazifop-butyl controlled the problem grasses effectively without causing any phytotoxicity to citrus.

Fluazifop-butyl can be used in several dicotyledonous crops for satisfactory control of annual and perennial grass at 0.1 to 0.3 kg/ha and 0.3 to 1.1 kg/ha, respectively (Plowman *et al*. 1980; Robinson *et al*.1982). Davidson *et al*. (1985) and Doll *et al*. (1983) have reported satisfactory to excellent control of *Elymus repens* at rates ranging from 0.25 to 0.36 kg/ha. Foy and Witt (1983) evaluated fluazifop for the control of *Panicum dichlotomiflorum*, *Setaria faberi* and *Echinochloa crus-galli*. They reported that fluazifop-butyl provided complete control of these annual grasses when applied at the rate of 0.56 kg/ha, 5 or 6 days after the first alfalfa harvest. Driver and Frans (1982) reported that fluazifop applied at rates ranging from 0.3 to 0.6 kg/ha provided excellent control of *Sorghum halepense* in soybeans. Fluazifop has also been reported to control *Eleusine indica*, *Brachiaria platyphylla*,and *Digitaria sanguinalis* in cucurbits and sweet potatoes (Locascio & Stall 1982, Monaco 1982).

In the present study, we examined the effect of single application of fluazifop-butyl on the degree and duration of control of annual and perennial grasses in citrus.

MATERIAL AND METHODS

The experimental work was done during 1983 and 1984 in citrus orchards of central Florida. The orchards were selected with more than 90% target grass species. Two annual and four perennial grass species were included in the study. The details are listed in Table 1. Fluazifop-butyl at 0.56 and 1.12 kg/ha was applied as post-emergence at the grass stages at different heights mentioned in Table 1. All applications were made using 375 ℓ/ha spray volume and 0.25% (v/v) non-ionic surfactant Ortho X-77 (trademark of Chevron Chemical Company, Richmond, CA, U.S.A.). The application pressure was maintained at 207 kPa. A tractor-mounted boom sprayer equipped with Teejet 8002 (trademark Spraying Systems Company, Wheaton, IL, U.S.A.) nozzle tips was used for spraying the plots. The tractor speed was maintained at 4 km/h. The plot size was 24 m x 3 m. The experiments were laid out as randomized complete block design with three replications. An untreated control was maintained in all experiments for comparison. The plots were assessed at 7, 14, 28, 42, 63, and 84 days after treatment application. The data were analyzed using analysis of variance procedure and treatment means were compared using least significant difference.

TABLE 1

Grass species included in the study

Name	Lifecycle[a]	Height at treatment (cm) 1983	1984	Date of Application 1983	1984
Brachiaria mutica	P	25	20	April	May
B. pilligera	A	15	37	Sept	Sept
Cynodon dactylon	P	20	20	April	May
Panicum maximum	A	50	45	April	June
P. repens	P	20	15	April	May
Paspalum notatum	P	25	30	April	May

[a]A = Annual; P = Perennial

RESULTS AND DISCUSSION

The effect of fluazifop-butyl at both rates was visible 7 days after spraying. Initial symptoms included desiccation and discoloration of leaves. In most of the cases, maximum control was observed 42 days after application. B. mutica was more tolerant to fluazifop-butyl. The highest control of this species recorded was 75% when treated with 1.12 kg/ha in 1983 (Table 2). In 1983, 84 days after treatment, plots treated with fluazifop butyl at both rates appeared similar to untreated control while in 1984, only

10 to 40% control was observed. Fluazifop-butyl provided up to 80% control of B. pilligera at 1.12 kg/ha (Table 3). The duration of control was also longer as even after 84 days, 40 to 60% control was recorded. C. dactylon appeared to be sensitive to fluazifop-butyl. The maximum control was up to 90% at 1.12 kg/ha and 85% at 0.56 kg/ha (Table 4). The rate difference at later dates was pronounced in 1984. At the end of 84 days in 1984, only 10% control was recorded at 0.56% kg/ha while at 1.12 kg/ha, the control was 80% The control of P. maximum varied from 25 to 90% kg/ha (Table 5). The control reached its peak at 42 days after treatment and then it dropped. Slightly higher control was observed in 1984 than in 1983. P. repens was relatively tolerant to fluazifop-butyl (Table 6) and its growth was temporarily suppressed. The maximum control was only 75% at 1.12 kg/ha in 1983. In 1983, the rates of fluazifop-butyl did not affect P. notatum control at any observation date; however in 1984, 1.12 kg/ha provided significantly higher control at all observation dates except at 7 days after treatment (Table 7). At 0.56 kg/ha, significant higher control was obtained in 1983 over 1984. The highest control was 85% at 1.12 kg/ha in 1984 at 63 days after treatment

TABLE 2

Effect of fluazifop-butyl on control of Brachiaria mutica

	Fluazifop-butyl (kg/ha)			
	0.56		1.12	
Days after Treatment	1983	1984	1983	1984
	% control			
7	10	15	25	20
14	50	20	50	30
28	60	50	65	60
42	70	50	75	70
63	15	30	25	60
84	0	20	0	40

TABLE 3

Effect of fluazifop-butyl on control of <u>Brachiaria piligera</u>

Days after Treatment	Fluazifop-butyl (kg/ha) 0.56 1983	0.56 1984	1.12 1983	1.12 1984
	-----% control			-----
7	10	10	10	20
14	30	60	40	80
28	40	80	40	80
42	55	70	65	70
63	60	65	70	70
84	40	50	60	60

TABLE 4

Effect of fluazifop-butyl on control of <u>Cynodon dactylon</u>

Days after Treatment	Fluazifop-butyl (kg/ha) 0.56 1983	0.56 1984	1.12 1983	1.12 1984
	-----% control			-----
7	10	10	15	15
14	60	40	62	50
28	70	70	70	80
42	85	75	90	80
63	70	40	80	90
84	40	10	50	80

TABLE 5

Effect of fluazifop-butyl on control of *Panicum maximum*

Days after Treatment	Fluazifop-butyl (kg/ha)			
	0.56		1.12	
	1983	1984	1983	1984
	% control			
7	27	40	25	50
14	45	50	42	60
28	48	60	77	80
42	62	80	80	95
63	40	70	55	90
84	30	60	50	85

TABLE 6

Effect of fluazifop-butyl on control of *Panicum repens*

Days after Treatment	Fluazifop-butyl (kg/ha)			
	0.56		1.12	
	1983	1984	1983	1984
	% control			
7	10	5	25	10
14	10	10	35	20
28	35	50	50	65
42	65	50	75	70
63	40	30	75	60
84	20	0	40	0

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Effect of fluazifop-butyl on control of Paspalum notatum

Days after Treatment	Fluazifop-butyl (kg/ha) 0.56 1983	0.56 1984	1.12 1983	1.12 1984
	% control			
7	20	10	25	20
14	50	40	55	75
28	60	50	65	75
42	70	30	75	85
63	60	10	70	60
84	45	5	55	40

Fluazifop-butyl was completely safe to young and old citrus trees and did not cause any phytotoxic symptoms to foliage. It appears that fluazifop-butyl controls annual grasses more effectively than perennial ones. Our other studies have also indicated that younger grass seedlings are more susceptible to fluazifop-butyl. Also, repeated application provided complete control of perennial grasses. Additional studies on multiple application, volume of application, and tank mix with other herbicides are in progress. We feel that fluazifop-butyl can be successfully used for the control of annual and perennial grasses in tree fruit crops without any risk.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the assistance of Mr. H. Kevin Hostler and Mrs. Brian S. Combs in completing these studies.

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GLUFOSINATE-AMMONIUM (HOE 39866): NEW RESULTS ON WEED CONTROL AND CROP TOLERANCE IN ORCHARDS

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ABSTRACT

In the years 1982 to 1984 the new non-selective foliar herbicide glufosinate-ammonium was tested under different conditions in orchards in Germany. A broad spectrum of annual and perennial weeds were controlled by 1.0 kg ai/ha, some species required higher rates. Two applications per season were sufficient to achieve weed control until harvest. A summer application in many cases was more efficient than a spring application. This may be explained by weeds being not fully emerged at the time of early application, or by the influence of higher temperature. Generally, glufosinate-ammonium controlled annual and perennial dicot weeds better than paraquat at equal rates. Combinations with other herbicides, e.g. simazine or phytohormones were useful under certain conditions. In bearing and non-bearing orchards, the crop was fully tolerant to the herbicide. This applied even where sucker control was obtained with glufosinate-ammonium.

INTRODUCTION

The new non-selective foliar herbicide® Basta, an aqueous solution containing 200 g/l glufosinate-ammonium (proposed common name), code number Hoe 39866, was developed by Hoechst AG for use in orchards and vineyards. First results were published by Schwerdtle *et al* (1981), Langelüddeke *et al* (1981, 1982), and a more detailed report was given by Langelüddeke & Bübl (1984) on results on efficacy and crop tolerance in vineyards. Since early 1984, Hoechst AG has a registration in Germany for use in vineyards. Further registrations were obtained in a number of other countries. In all other major markets the registration process has been initiated. - The objective of the further experimentation was to obtain broader data on spectrum, dosage rates and on crop tolerance to establish recommendations for practical use. Tank mixtures especially with simazine were also tested more intensively.

MATERIALS AND METHODS

The trials were conducted in the years 1982 to 1984 in orchards in different parts of Germany. Generally two applications were made, the first in spring (mid April until beginning June), and the second one in summer (end June until beginning August). The rates used for spring application were 1.0 or 1.5, and for summer application 1.0 kg a.i./ha of glufosinate-ammonium. In all trials paraquat was used as standard treatment. All treatments were applied to the tree rows, the plot size ranged from 20 to 100 m^2, and the number of replicates from 2 to 4. The spray volume was 300 to 600 l/ha, and the nozzles types were Teejet 11002, 11004 or OC 06. Dosage rates were related to the actual treated area.

® Basta: registered trade mark of Hoechst AG

Assessments of efficacy and crop tolerance were made using the usual scoring system 0 to 100, 0 indicating no effect, 100 complete kill of the green plant parts. At the beginning of all trials the coverage of the weed species was noted, and again prior to second application.

In crop tolerance trials in young plantations 5 to 10 trees per treatment were used. The lower part of the trunk was treated as usual in practice. Suckers of older trees were treated in the same way as weeds.

TABLE 1

Efficacy (in %) of glufosinate-ammonium and paraquat (both at 1 kg/ha) on major weeds 2 and 4-6 weeks after application

Weed species	Number of trials	glufosinate-amm.		paraquat	
		2	4-6	2	4-6
Dactylis glomerata	5	77	75	88	73
Elymus repens	9	82	75	83	74
Festuca rubra	6	94	94	99	93
Holcus lanatus	10	93	93	95	96
grasses generally*	52	90	74	94	80
Galium aparine	22	81	78	66	65
Lamium purpureum	6	98	99	98	96
Polygonum aviculare	5	100	99	77	69
Senecio vulgaris	12	99	98	99	91
Stellaria media	20	93	79	93	87
Urtica urens	9	60	50	46	39
Veronica hederaefolia	5	99	99	99	96
Cirsium arvense	47	93	82	87	69
Convolvulus arvensis	23	86	69	68	56
Glechoma hederacea	19	89	73	59	34
Polygonum amphibium-terrestre	9	71	54	61	37
Ranunculus repens	18	58	47	80	75
Rumex crispus	12	90	80	70	44
Taraxacum officinale	38	96	94	74	63
Urtica dioica	6	85	85	57	28

* Species not identified, mostly mixtures of perennial grasses

RESULTS

Efficacy trials

In all trials, glufosinate-ammonium showed a good herbicidal efficacy on weeds within 1 or 2 weeks following application. Detailed results as compared to paraquat are given in tables 1 and 2. In table 1, the effects of 1 kg/ha of both products on the major weeds are compared, and in table 2 the efficacy of both products for spring and summer applications is summarized for weed groups.

TABLE 2

Efficacy (in %) of glufosinate-ammonium and paraquat on groups of weeds after spring (I) and summer (II) application

Weed groups	Appl. time	Number of trials	glufosinate-ammonium 1,0		glufosinate-ammonium 1,5		paraquat 1,0 kg/ha	
			2*	4-6*	2*	4-6*	2*	4-6*
Annual grasses	I	10	88	88	93	96	94	94
	II	7	99	99	-	-	99	98
Perennial grasses	I	48	87	77	91	86	92	81
	II	42	92	82	-	-	94	86
Annual dicots	I	59	80	78	92	83	78	70
	II	44	94	91	-	-	89	84
Perennial dicots	I	97	83	72	86	78	69	51
	II	96	86	84	-	-	80	67
Horsetails (*Equisetum arvense*)	I	3	83	76	82	79	37	26
	II	7	91	80	-	-	83	79
Average of all weeds	I	217	83	75	89	82	78	65
	II	196	89	85	-	-	86	76

* 2 and 4-6 weeks after application

Generallay, the control of grass weeds with 1 kg/ha glufosinate-ammonium was equal to or somewhat weaker than the same rate of paraquat, the performance of both products being better in summer than in spring. At the second assessment the effect on many perennial grasses was lower than at the early assessment, as regrowth had already started. With spring applications, however, the higher rate of glufosinate-ammonium gave better results.

Annual and particularly perennial dicots were better controlled by 1 kg/ha glufosinate-ammonium than by 1 kg/ha paraquat; and again the summer applications of both products performed better than spring applications. Clear advantages of glufosinate-ammonium over paraquat were observed for *Galium aparine*, *Polygonum aviculare*, *Convolvulus arvensis*, *Glechoma hederacea*, *Rumex crispus*, *Taraxacum officinale* and *Urtica dioica*. However, the differences between spring and summer applications varied from species to species as can be seen in table 3: For glufosinate-ammonium, no differences could be found with timing on Taraxacum officinale; but Galium aparine was only well controlled in summer; paraquat showed a similar tendency. The same good efficacy of summer treatments of glufosinate-ammonium was found in Convolvulus arvensis, paraquat being weaker at both application times. The control of Urtica urens and Polygonum amphibium-terrestre was poorer with both products, increasing the dosage rate of glufosinate-ammonium increased the efficacy. However, Ranunculus repens could not be efficiently controlled at 1 or at 1.5 kg/ha glufosinate-ammonium.

TABLE 3

Efficacy (in %) of glufosinate-ammonium and paraquat (both at 1 kg/ha) on some dicots after spring (I) and summer (II) applications

Weed species	Applic. time	Number of trials	glufosinate-ammonium		paraquat	
			2*	4-6*	2*	4-6*
Galium aparine	I	13	71	64	51	46
	II	9	95	98	89	93
Convolvulus arvensis	I	7	69	43	46	37
	II	16	94	81	78	64
Taraxacum officinale	I	20	95	94	70	60
	II	18	97	95	79	67

* Assessment 2 and 4-6 weeks after application

In a number of trials glufosinate-ammonium was tank mixed with simazine. A particular orchard was mainly infested with perennial grasses, some Taraxacum and some annual dicots. Due to the severe infestation with perennials, 3 applications of glufosinate-ammonium were necessary to keep the tree rows sufficiently clean until harvest. An addition of simazine to the first or second application improved the glufosinate effect especially on the grasses so much that only one follow-up application was necessary. In addition the new emergence of annual dicots was suppressed for a long period.

In trial sites which were heavily infested with Ranunculus repens, Equisetum arvense or Polygonum amphibium-terrestre, the effect of glufosinate-ammonium could be improved by the addition of MCPA. In a few trials, a severe weed infestation was controlled by a mixture of glufosinate-ammonium (1.5 kg/ha), MCPA (2.0 kg/ha) and simazine (2.5 kg/ha) for a period of 3 to 6 months.

In all efficacy trials, glufosinate-ammonium at normal or increased rates (1.0 or 1.5 kg/ha, resp.) with 1 or 2 or 3 applications per season alone or in tank mixtures with simazine or MCPA, was completely tolerated by the trees.

Crop tolerance trials

Two different types of trials were conducted:

1. Tolerance tests in the year after planting of pome or stone fruits: a spring application of 1.5 kg/ha, followed by a summer application of

1.0 kg/ha glufosinate-ammonium were conducted by the German Plant Protection Service in 1984; in none of these trials phytotoxicity was observed.

2. Tolerance tests in bearing orchards especially in stone fruits for sucker control: Two applications (1.5 followed by 1.0 kg/ha glufosinate-ammonium) were tolerated by the mother trees; but the suckers were successfully controlled for a certain period. An example of the efficacy is given in table 4. Similar observations have been made in a 10 years old apple plantation of 15 different varieties with varying sucker growth; glufosinate-ammonium was applied in spring at 1.5 or 3.0 kg/ha without follow-up treatments. In these and other trials no damage of the foliage or of the bark could be observed even in the year following application.

TABLE 4

Effect on plum suckers, efficacy (in %) of glufosinate-ammonium and paraquat; two applications

Treatments	kg a.i./ha	days after 1st application 10	42	52	74*	87*
Untreated (coverage)		(30)	(50)	(50)	(53)	(57)
Glufosinate-ammonium	1.5 + 1.0	82	62	38	95	95
Paraquat	1.0 + 1.0	78	37	14	91	92

Applications May 15 and July 9

* 22 and 35 days after 2nd application

DISCUSSION

Efficacy trials

In the orchard trials for 1982 to 1984 earlier observations on the performance of glufosinate-ammonium (Schwerdtle et al 1981) were confirmed: The relatively quick initial effect on green plant parts, the rapid kill of annual weeds and suppression of perennial weeds for some weeks. Generally 2 applications per season will be sufficient to keep the tree rows weed free until harvest.

The comparison of spring and summer application showed, that the efficacy of glufosinate-ammonium and of paraquat was better in summer than in spring. However, species varied: Convolvulus arvensis control in spring was very poor, as this weed was not sufficiently emerged until mid May. For Taraxacum officinale there was practically no difference between times. The summer application was probably more effective due to the higher temperatures; Donn (1982) was the first to find an influence of temperature, and the observations of Langelüddeke & Bübl (1984) showed a similar dependence.

Earlier findings were confirmed that the effect of glufosinate-ammonium on perennial dicots (as well as on annual dicots) was better and that the regrowth of these species was suppressed for a longer time than after paraquat. However, an increase of the rate to 1.5 kg/ha or addition of simazine could increase the effect especially on perennial grasses and the germination of new seeds.

The spectrum covered by glufosinate-ammonium under German conditions has already been reported by Langelüddeke & Bübl (1984). The following species can be added:

At 1 kg/ha: Festuca pratensis, Lolium multiflorum, Poa pratensis, Bellis perennis, Epilobium adnatum, Matricaria inodora, Veronica agrestis, Veronica hederaefolia.

At 1.5 kg/ha: Alopecurus pratensis, Bromus mollis, Poa trivialis, Urtica urens.

Crop tolerance

No phytotoxicity was observed in any of the bearing stone or pome orchards. This applied for up to 3 applications per season, and including tank mixtures with simazine and MCPA. Only leaves which were directly hit by the spray showed the necrotic symptoms, but no symptoms of translocation were found. For the specific sucker treatments with 2 applications, the foliage was scorched but new suckers were healthy, so was the foliage of the mother tree. These results agree with results from overseas countries on numerous species. The only report of phytotoxicity to fruit trees was given by Majek (1985) who observed damages to the bark of bearing peach trees after an autumn application of a 3.5 % solution of glufosinate-ammonium. However, this concentration was much higher than that used in our own trials (highest concentration 0.5 %).

Even young trees treated in the year after planting were generally tolerant if the product was applied with care. However, the product should not be applied to plants with non-lignified bark in young orchards or vineyards.

ACKNOWLEDGEMENTS

The authors wish to thank all technicians of Hoechst AG who conducted or evaluated the trials and all farmers who co-operated in carrying out these trials.

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TOLERANCE OF RASPBERRY TO PENDIMETHALIN ALONE AND IN COMBINATION WITH SIMAZINE

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ABSTRACT

Early spring treatment with pendimethalin alone 1.32, 1.98, 2.64 kg a.i./ha and in mixture with simazine 1.32+1.00, 1.32+1.50, 1.98+1.00,1.98+ 1.50 kg a.i./ha were carried out in field trials in raspberry plantations. The influence of these herbicides on yield and quality of fruit, the mean height of new canes and the total number of canes per metre length were assessed together with weed control.

INTRODUCTION

Pendimethalin is a dinitroaniline soil applied herbicide that is recommended for use on many different crops (Deemes) 1980, Simon 1979, Sprankle 1974). According to Clay (1978) and Davison (1980) pendimethalin can be used safely in strawberries, even though it reduced leaf growth. The objective of these experiments was to evaluate the tolerance of raspberry to pendimethalin alone and in combination with simazine.

MATERIALS AND METHODS

During 1982-84 field trials were carried out at Plant Protection Institute - Kostinbrod on a leached chernozem-smolnitsa soil (o.m. 3.58 % and pH 6.2) and at Institute of Mountain Animal Husbandry on light grey soil (o.m. 1.98 % and pH 5.3). A two-year old and a six-year old raspberry plantation of cv Shopska Alena were used. The experiment was laid down after the standard methods of Konstantinov replicated four times, the area of test plot being 22 sq.m. The interrow spacing was 2.20 m and the length of each experimental plot - 5 m.

Pendimethalin, 33 % e.c. was applied at 1.32, 1.98 and 2.64 kg a.i./ha alone or in mixture with simazine 50 % w.p., at rates - 1.32+1.00, 1.32+1.50,1.98+1.00, 1.98+1.50 kg a.i./ha. Each year the herbicides were applied to the same area with a Hand Sprayer at a volume rate-600 l/ha. The soil was well cultivated in advance. All treatments were applied on 15 April 1982, 7 April 1983 and 16 April 1984.

Weed control was assessed 40 and 80 days after spraying by counting the individual weed species present in a 1 sq.m. area in each plot. Crop tolerance was evaluated visually at intervals using the EWRS scale 0-9. The height of the young canes was measured in September and the total number (per linear metre) was counted in Oktober. The yield and quality of the fruit were determined by using standard methods.

RESULTS AND DISCUSSION

Table 1 shows average percentage control of grass and broad-leaved weeds in raspberries. Pendimethalin applied alone at the rate of 1.32 kg a.i./ha provided good weed control more than 90% for Amaranthus retroflexus, Chenopodium polyspermum and Setaria viridis, and more than 80% for Chenopodium album, Polygonum lapathifolium, Stellaria media. The control by pendimethalin wasnot satisfactory for Galinsoga parviflora and Sinapis arvensis.

TABLE 1

Average percentage control of grass and broad-leaved weeds in raspberries (1982-1984)

Weed species	Pendimethalin (kg a.i./ha)			Pendimethalin + simazine			
	1.32	1.98	2.64	1.32 +1.00	1.32 +1.50	1.98 +1.00	1.98 +1.50
Amaranthus retroflexus	99	99	100	100	100	100	100
Capsella bursa pastoris	79	82	89	99	100	100	100
Chenopodium album	88	90	94	100	100	100	100
Chenopodium polyspermum	92	95	99	100	100	100	100
Euphorbia peplus	79	81	85	93	100	95	100
Galinsoga parviflora	72	76	79	86	99	100	100
Bilderdykia convolvulus	84	85	90	92	95	93	98
Polygonum lapathifolium	88	90	94	96	100	100	100
Setaria viridis	94	97	99	98	98	100	100
Senecio vulgaris	69	72	79	82	92	83	99
Sinapis arvensis	71	75	77	92	99	94	100
Stellaria media	83	89	96	99	100	100	100

Mean no. of grass weeds / sq.m. in untreated control 198
Mean no. of broad-leaved weeds/sq.m. in untreated control 227

Pendimethalin in mixture with simazine shows an exellent weed control of both grass and broad-leaved weeds. The results of the investigations correlated well those of Simon (1979), who shows that pendimethalin is an exellent addition to standard triazine products which may not be fully effective against annual grass weeds. Thus an applications of 1.32 kg a.i./ha pendimethalin, in combination with 1.50 kg a.i./ha simazine, provided a full season's weed control in raspberry plantation.

The effect of pendimethalin, applied alone or in mixture with simazine on yield of raspberries, height of the new canes and total number of canes per metre length over the period of three years of the investigation are presented in Table 2. In comparison with the untreated without cultivation control,all treatments with pendimethalin alone or in combination with simazine provided a higher yield, but as compared to untreated with cultivation the yield was almost the same. The highest yield in 1982,1983 and 1984 was obtained from plots treated with pendimethalin 1.32 kg a.i./ha with simazine 1.50 kg a.i./ha.

TABLE 2

Fruit and cane records (1982-1984)

Treatments	Rate kg a.i. /ha	Yield (t/ha)			Mean ht (cm) new canes			Cane per metre length		
		1982	1983	1984	1982	1983	1984	1982	1983	1984
Untreated without cultivation	-	2.9	1.7	1.8	192	184	92	33	38	24
Untreated with cultivation	-	4.6	1.9	2.9	226	216	115	46	45	29
Pendimethalin	1.32	4.4	2.0	3.1	216	218	216	47	42	34
Pendimethalin	1.98	4.2	2.3	3.3	212	206	120	46	44	31
Pendimethalin	2.64	4.0	1.9	2.9	206	207	98	39	42	27
Pendimethalin + simazine	1.32 +1.00	4.9	2.2	3.4	220	223	121	49	49	32
Pendimethalin + simazine	1.32 +1.50	5.3	3.1	3.8	226	230	133	52	56	36
Pendimethalin + simazine	1.98 +1.00	5.1	2.9	3.2	218	226	128	44	51	33
Pendimethalin + simazine	1.98 +1.50	4.8	2.4	3.0	216	225	124	39	40	30

Observations during the period of growing of the raspberries showed that the plants of all plots treated with pendimethalin alone or in combination with simazine developed normally. No phytotoxic action of herbicides was observed. Pendimethalin applied alone at the rate more than 1.98 kg a.i./ha slightly inhibited the growth of new canes. In comparison with untreated with cultivation control, the height of the young canes in a plots treated with pendimethalin alone at the rate 2.64 kg a.i./ha was reduced by 20 cm (1982), 9 cm (1983) and by 17 cm (1984). This growth reduction may be du to the fact that during the spraying in 1982 and 1984, young canes were 20-25 cm high, and at that stage pendimethalin used at high rates inhibits the growth. The best growth of the new canes were from plots treated with pendimethalin 1.32 kg a.i. /ha plus simazine - 1.50 kg a.i./ha.

The herbicides did not reduce the total number of new canes. In plots treated with pendimethalin 1.32 kg a.i./ha alone and in combination with simazine 1.50 kg a.i./ha, there were 5 to 11 more than in the cultivated control.

TABLE 3

Quality of the fruits - 1982

Treatments	Rate kg a.i. /ha	Dry mater content %	Total sugar content %	Titratable acid (as citric) %	Ascorbic acid mg %
Untreated witout cultivation	-	8.2	3.14	1.74	40.48
Untreated with cultivation	-	7.0	2.14	1.85	42.24
Pendimethalin	1.32	7.4	3.22	1.88	41.20
Pendimethalin	1.98	7.2	2.94	1.84	41.92
Pendimethalin	2.64	7.6	2.82	1.82	39.90
Pendimethalin + simazine	1.32 +1.00	7.0	2.67	1.65	41.12
Pendimethalin + simazine	1.32 +1.50	7.3	3.21	1.72	41.98
Pendimethalin + simazine	1.98 +1.00	7.1	2.93	1.69	39.20
Pendimethalin + simazine	1.98 +1.50	6.9	2.86	1.73	38.90

The data of Table 3 shows that pendimethalin applied alone or in combination with simazine did not change the quality of the fruit as measured by dry mater content, total sugar, titratable acid and ascorbic acid content.

The results of this work has shown that pendimethalin in combination with simazine is promising herbicide for the pre-emergence control of annual grass and broad-leaved weeds in raspberry plantations.

ACKNOLEDGEMENTS

Thanks are due to P.L.Orwick.Ph.D. and Dr.B. Baltovski, Cyanamid Company for providing information on pendimethalin. Thanks are also due to the staff of PPI and IMAH (T. Misheva, M.Vulcheva and M. Tosheva) who assisted with experiments.

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EFFECT OF FLUAZIFOP-BUTYL ON ANNUAL AND PERENNIAL GRASS WEEDS AND STRAWBERRY PLANTS

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ABSTRACT

The effects of a range of rates of fluazifop-butyl assessed on the control of annual and perennial grasses in strawberries and on its influence on the growth and cropping of strawberries. Annual grass weeds were easily controlled with rates of 0.75 kg a.i./ha, but Elymus repens required higher rates. There were no adverse effect of fluazifop-butyl on the growth and cropping of strawberries or on the quality of fruits or leaf pigments.

INTRODUCTION

Fluazifop-butyl (PP009) is recommended for annual and perennial grass weed control in broad-leaved crops (Finney & Sutton 1980, Lwson & Wiseman 1982, Wheeler 1980, Sarpe & Dunu 1980). According to Plowman et al (1980) strawberries shown to be tolerant to fluazifop-butyl by post-emergence spraying at rates at least twice those required for effective grass weed control.

The purpose of this study was to estimate the effect of fluazifop-butyl on annual and perennial grass weeds and strawberry plants.

MATERIALS AND METHODS

Two field trials and one growth room study were carried out the strawberry cv Pokahontas. The first field trial was at the experimental field of Plant Protection Institute - Kostinbrod, on a leached chernosem-smolnitsa soil containing 3.58 % o.m. and pH in KCl 6.2; the secod one at the Cooperative Farm near by Botevgrad. The sites were infected by Amaranthus retroflexus, Chenopodium album and severely with Setaria spp., Echinochloa crus-galli and Elymus repens. The treatments were replicated 4 times on plots 10 square metres. Fluazifop-butyl was applied at 0.50, 0.75, 1.00, 1.50, 2.00 and 2.50 kg a.i./ha as a product "Fusilade".

At the time of spraying the annual grass weeds were at 2-4 leaf stage and at stage of earing, Elymus repens was 10-15 cm high.

Observation on the selectivity of fluazifop-butyl on the strawberry plants and efficiency in weed control were made using EWRS scale.

In the growth room experiment plants were plased in a

Hoagland solution containing differents concentrations of fluazifop-butyl (0, 0.1, 0.5, 1, 2 and 5 ppm) at 20° C, irradiated with high pressure mercury vapour lamps with fluorescent bulbs. A photoperiod of 16 hours light was alternated by a period of 8 hours of darkness.

The effect of fluazifop-butyl on pigments was measured by a spectrophotometer using wave lengths of 663, 664 and 452 nm respectively.

RESULTS AND DISCSSION

The effect of fluazifop-butyl on control of annual weeds is shown in table 1.

TABLE 1

Effect of different rates and application times of fluazifop-butyl on control of annual grass weeds in strawberries. (Botevgrad-1980, 1981)

Application weeds-G.S.	Rates kg a.i./ha	Percentage kill DAT		
		20	35	40
Early post-emergence 2-4 leaves (1981)	0.50	85	92	95
	0.75	99	100	100
	1.00	100	100	100
Late post-emergence earing (1980)	0.50	58	69	73
	0.75	64	73	88
	1.00	75	82	91
	Control	0	0	0

The date frpm table 1 shows clearly that fluazifop-butyl controls annual grass weeds in stage 2-4 leaves much more rapidly than the late applications in earing growth stage. All the annual grass seedlings died 20 days after treatment with fluazifop-butyl 0.75 kg a.i./ha.

Table 2 provides information about effect of different rates of fluazifop-butyl on Elymus repens, grown from undisturbed rhizomes in strawberry plantation.

The effect of fluazifop-butyl applied at 0.5 and 1.0 kg a.i./ha is not satisfactory. Elymus repens kill almost complete at a dose of 2 kg a.i./ha.

The effect of fluazifop-butyl on growth of strawberry plants is shown in table 3.

TABLE 2

Effect of different rates of fluazifop-butyl on control of Elymus repens - undisturbed rhizomes. (Kostinbrod-1981)

Application-growth stage	Rates kg a.i./ha	Score-EWRS scale DAT				Plants per 1 sq/m 60 days after spraying	
		15	30	60	90	Number	Fresh weight (g)
Elymus repens 15-20 cm height	0.50	8	7	8	8	1034	487
	1.00	7	6	6	5	903	388
	1.50	6	6	5	4	830	353
	2.00	5	4	3	2	786	331
	2.50	5	3	2	2	654	283
	Control	9	9	9	9	1332	492

EWRS scale: 9 = no effect on Elymus repens
1 = total withering of Elymus repens plants

TABLE 3

Effect of fluazifop-butyl on growth of strawberry plants

Rate kg a.i./ha	Leaves*				Roots*		Number of flowers	Number of rooted runners as % of control
	Number	Width (cm)	Length (cm)	Fresh weight (g)	Primary root length	Secondary root development**		
0.50	13	6.9	8.3	26.8	21.6	9.5	16.6	101
1.00	14	6.4	8.2	26.6	22.1	9.4	16.8	105
1.50	13	6.3	8.4	27.1	21.8	9.6	16.2	103
2.00	13	6.8	8.3	26.9	21.9	9.4	16.4	106
2.50	15	6.7	8.6	26.5	22.3	9.7	16.7	104
Control	13	6.6	8.4	26.7	21.7	9.6	16.6	100

* - Average of 20 plants
** - Rated 1 to 10 as follows : 1=almost no secondary roots
10=very many well branched roots

Observation were made periodically to determine the obvious effect of fluazifop-butyl on strawberry plants. No phytotoxical action of fluazifop-butyl occured. The selectivity of fluazifop-butyl towards strawberry plants is well established. Fluazifop-butyl, applied during the growing and also at the flowering stage of the strawberry provide to be very safe, even at the maximum application rates up to 2.50 kg a.i./ha. There was no difference in number, width, length and fresh weight of the leaves of treated plants and untreated ones. Primary root length of plants sprayed with fluazifop-butyl was the same as that of untreated plants. No effect of fluazifop-butyl on secondary root development was observed. The average number of rooted runners and the number of flowers were not less in any of the fluazifop-butyl treatments than in the control.

Mean yield of strawberries and the quality of the fruits in treated and untreated plants is shown in table 4.

TABLE 4

Effect of fluazifop-butyl on yield of strawberries and quality of the fruits.

Rate kg a.i./ha	Mean yield as % of control	Quality of the fruits			
		Ascorbic acid mg%	Titratable acid % as citric	Glucose %	Sucrose %
0.50	100	66.68	0.578	8.94	0.94
1.00	102	66.62	0.568	8.92	0.93
1.50	101	66.65	0.571	8.89	0.98
2.00	104	66.72	0.579	8.90	0.90
2.50	104	66.73	0.573	8.93	0.92
Control	100	66.67	0.577	8.92	0.91

Fluazifop-butyl does not change the quality of the strawberries.

Growth room trials were carried out to determine the presence or abcence of any influence of fluazifop-butyl on the content of the pigments in strawberry plants. Analysis of the data of table 5 shows that fluazifop-butyl does not exert any influence on the chlorophyll or carotene contents.

TABLE 5

Effect of fluazifop-butyl on contents of pigments in strawberry leaves mg/1 g fresh wt.

Rate kg a.i./ha	Chlorophyll A	Chlorophyll B	Carotene
0.50	0.447	0.844	1.033
1.00	0.449	0.846	1.029
1.50	0.452	0.842	1.033
2.00	0.448	0.846	1.038
2.50	0.450	0.843	1.034
Control	0.449	0.844	1.034

The results of this work shown thatfluazifop-butyl is a promising herbicide for post-emergence control of annual grass weeds and Elymus repens in strawberry plantations.

ACKNOLEDGEMENTS

The authors wishes to acknoledge the Cooperative Farm in Botevgrad who provided trial sites and thanks are du to the staff of PPI (T.Misheva, M. Vulcheva and M. Tosheva), who assisted us with the experiments.

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THE TOLERANCE OF BLACKCURRANTS TO SHOOT AND ROOT APPLICATIONS OF 30 HERBICIDES

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ABSTRACT

The activity of 30 herbicides was tested on container-grown blackcurrants using separate applications to the shoots or to the roots of plants growing in sand culture. Pendimethalin, alloxydim sodium, fluazifop-butyl and sethoxydim had no detectable effect in any test. Oxadiazon had no adverse effect except as an overall spray in spring. Oxyfluorfen sprays in spring were more damaging. Ethofumesate sprays resulted in long-term leaf distortion.

Some triazine herbicides with post-emergence activity were safe as directed sprays. Apart from trietazine + simazine they were more toxic than simazine when applied to the roots, but safer than diuron, a recommended herbicide. Methazole was also much safer than diuron when applied to shoots or roots. Hexazinone was very toxic as a shoot or root application as was root treatment with chlorsulfuron. Benazolin and triclopyr were more damaging than clopyralid. Overall sprays of phenmedipham, pyridate and AC 222293 caused initial damage, subsequently outgrown. Bentazone caused little damage except as an overall spray in summer. Glufosinate was less damaging than paraquat.

INTRODUCTION

New herbicide treatments have been needed for blackcurrants in the U.K. because of difficulties in controlling annual weeds resistant to simazine and for perennial weed control. Field experiments involving large numbers of herbicides are expensive and results often unreliable because of variable weather following spraying but pot experiments are an efficient way of screening the herbicide tolerance of fruit crops (Clay 1980). Experiments were therefore carried out at the Weed Research Organization, Oxford using techniques involving separate treatment of shoot and root systems (Clay 1980). With these methods response to new herbicides could be compared to standard herbicides and promising treatments selected for field testing.

MATERIALS AND METHODS

The blackcurrant cv Baldwin was used in all experiments. All plants were grown outdoors and received routine applications of pesticides during the growing season.

Experiment 1 Response to shoot treatments in winter or spring.

1-year-old bushes were potted in John Innes compost in 25 cm diam. polythene pots in November 1980. Bushes were pruned in December to leave three or four main shoots 40 cm long. Pots were watered on the soil surface when necessary. The treatments listed in Table 1-3 were applied on 27 January to dormant shoots, on 12 March at bud burst (most buds up to 1 cm long with leaves showing) or on 8 April, (new shoots up to 5 cm long, 1-2 expanded leaves/bud). Herbicides were applied using a laboratory pot sprayer either overall or directed to the basal 10 cm of each bush on one side. Herbicide was kept off the soil by temporarily covering it with paper. The herbicides used were the sole formulations available in the U.K. apart from benazolin ethyl ester 10% e.c., chlorsulfuron, 20% w.s.p; methazole 75% w.p.; oxyfluorfen 24% e.c.; terbuthylazine 80% w.p; clopyralid 10% a.c.; triclopyr amine salt 36% e.c.

The sprayer was fitted with a Spraying System 8002E Teejet at 210 kPA pressure to give a volume rate of 370 l/ha for both overall and directed applications. For phenmedipham treatments the spray target was lowered to give a volume rate of 240 l/ha. Pots were returned outside after spraying but kept for 3 days under a transparent cover for rain protection. There were three replicates of each treatment and pots were set out in randomised blocks. Plant response was recorded at intervals by scoring for damage using a 0-9 scale, 0 = plant dead, 9 = healthiest untreated plant. The type of damage symptoms were recorded. Shoot length and fresh weight were measured at the end of the experiment.

Experiment 2 Response to shoot treatment in summer

Plants grown as for Experiment 1 were cut down on 19 May and four shoots allowed to regrow. The herbicides listed in Table 4 were sprayed overall on 15 July when most shoots were 30 cm long. Formulation and spray details as for Experiment 1; glufosinate, 20% a.e. and AC 222293, 50% w.p. were also included. After spraying bushes were protected from rain as above then set out outside in four randomised blocks. Plant condition was scored at intervals; shoots were cut off on 19 August and fresh weight recorded.

Experiment 3 Response to root applications

The experimental method followed that described by Clay (1980). In late March rooted cuttings 15 cm long were transplanted into sand in 25 cm diam. pots, three per pot and watered with nutrient solution as necessary. Before herbicide treatment pots were placed in foil saucers outside but with rain protection. Treatments were applied on 30 April when most cuttings had one actively-growing shoot, 3-6 cm long. The formulations used were the same as in previous experiments. Four doses of each herbicide were used with three replicates. The appropriate quantity of herbicide in 500 ml of nutrient solution was added to the sand surface. Plant condition was scored at intervals after treatment and final shoot fresh weight recorded.

RESULTS

Experiment 1 Response to shoot treatments in winter or spring

Diuron caused no detectable damage as an overall spray in winter and as a directed spray in spring (Table 1). Overall spray with 6 kg/ha at bud burst and 2 and 6 kg/ha in April caused leaf necrosis and growth reduction. Methazole (2 and 6 kg/ha) applied as an overall spray in April caused some necrosis. Directed treatments were safe. Ethofumesate applied in winter or at bud burst caused distortion of some leaves growing out in spring. Leaf surfaces adhered as leaves expanded causing severe malformation and stunting. However final shoot weight was unaffected. Pendimethalin (2 and 6 kg/ha) as an overall spray had no adverse effect on leaf growth and final shoot weight apart from slight leaf stunting with the highest rate applied in April. Oxadiazon (2 and 6 kg/ha) appeared to be safe as an overall spray in winter but application at bud burst caused severe necrosis and stunting of expanding leaves although final shoot weight was unaffected by the lower dose. Directed sprays in April also caused necrosis of leaves on treated shoots. Oxyfluorfen (0.8 and 2.5 ka/ha) as an overall spray at bud burst caused severe necrosis and stunting of leaves the higher rate leading to shoot weight reduction. Directed sprays at bud burst or in April caused severe necrosis and stunting of leaves on sprayed shoots.

TABLE 1

The effect of overall (O) and directed (D) applications of residual herbicides on blackcurrants (Experiment 1)

			Application date					
			27 January		12 March		8 April	
Herbicide	Dose (kg/ha)	Appl. method	Score+ 7 May	F.wt(g) 19 May	Score 7 May	F wt* 19 May	Score+ 21 May	F wt.* 28 May
Diuron	2.0	O	8.0	148	7.7	3.07	6.7	2.06
"	6.0	O	8.0	124	6.7	2.99	4.0	1.64
"	2.0	D	-	-	8.0	3.10	8.7	2.08
"	6.0	D	-	-	8.0	3.12	9.0	2.13
Methazole	2.0	O	-	-	8.0	3.12	7.3	2.12
"	6.0	O	-	-	8.0	3.13	6.3	2.03
"	2.0	D	-		8.0	3.16	9.0	2.19
"	6.0	D	-		8.0	3.16	8.7	2.09
Etho-fumesate	2.0	O	7.3	126	7.0	3.05	-	-
	6.0	O	6.7	136	6.0	3.01	-	-
"	2.0	D	-	-	7.7	3.06	-	-
"	6.0	D	-	-	7.3	3.07	-	-
Pendi-methalin	2.0	O	8.0	128	8.0	3.14	8.0	2.07
	6.0	O	8.0	134	8.0	3.08	7.0	2.14
"	2.0	D	-	-	8.0	3.12	9.0	2.15
"	6.0	D	-	-	8.0	3.09	8.7	2.16
Oxadiazon	2.0	O	8.0	118	6.3	3.03	-	-
"	6.0	O	8.0	137	4.7	2.84	-	-
"	2.0	D	-	-	7.3	3.03	-	-
"	6.0	D	-	-	7.0	3.10	-	-
Oxy-fluorfen	0.8	O	-	-	6.0	2.99	-	-
	2.5	O	-	-	4.7	2.83	-	-
"	0.8	D	-	-	7.3	2.94	7.7	2.04
"	2.5	D	-	-	7.0	3.04	7.0	2.03
Untreated			7.9	134	7.9	3.12	9.0	2.12
S.E.± (untreated v treated)			0.16	11.3	0.23	0.074	0.27	0.056

+ Score of plant condition, 0 = dead, 9 = healthiest control.
* Fresh wt. shoots/plant, Log_{10} (V + 1)   - not treated.

Atrazine, cyanazine, terbuthylazine and trietazine + simazine had no adverse effect as overall sprays at bud burst but in April caused chlorosis and necrosis of sprayed leaves as did desmetryne (Table 2). The higher dose of desmetryne as a directed spray caused localised leaf damage. These symptoms were outgrown and there was no reduction in final shoot weight except with the higher dose of atrazine. Hexazinone caused leaf damage when applied overall at bud burst or in April, the April treatments reducing final shoot weight. Directed sprays caused necrosis of leaves on treated shoots particularly at the higher dose but shoot weight was unaffected. Bentazone (1.5 and 4.5 kg/ha) applied overall at bud burst caused no adverse effects but in April damage was severe. A directed spray was less damaging.

TABLE 2

The effect of herbicides applied to blackcurrants at bud burst (12 March) and first open flower (8 April) (Experiment 1)

Application date		12 March				8 April			
Application method		Overall		Directed		Overall		Directed	
Herbicide	Dose (kg/ha)	Score+ (0-9) 7 May	F.wt* 19 May	Score+ (0-9) 7 May	F.wt 19 May	Score+ (0-9) 21 May	F.wt* 28 May	Score+ (0-9) 24 Apr	F.wt 28 May
Atrazine	1.5	8.0	3.05	8.0	3.17	6.7	2.09	8.5	2.16
	4.5	8.0	3.06	8.0	3.16	5.3	1.88	8.7	2.08
Cyanazine	1.5	8.0	3.11	8.0	3.08	6.7	2.10	8.5	2.08
	4.5	8.0	3.03	8.0	3.08	6.0	1.99	8.7	2.18
Desmetryne	0.4	-	-	-	-	7.0	2.09	8.3	2.09
	1.1	-	-	-	-	6.3	1.98	7.7	2.14
Hexazinone	1.0	7.3	3.06	8.0	3.07	4.3	1.71	7.7	2.17
	3.0	7.0	3.03	7.3	3.07	3.3	1.25	7.3	2.08
Terbuthyl-	1.5	8.0	3.10	8.0	3.11	6.7	2.12	8.3	2.11
azine	4.5	8.0	3.08	8.0	3.13	6.3	2.05	9.0	2.06
Trietazine	1.7	8.0	3.16	8.0	3.11	7.0	2.04	8.0	2.14
+simazine	5.1	8.0	3.17	8.0	3.11	6.3	2.06	9.0	2.09
Bentazone	1.5	8.0	3.10	8.0	3.05	3.0	1.27	6.3	2.03
	4.5	7.0	3.02	8.0	3.3	2.3	1.00	6.0	2.04
Asulam	1.7	-	-	-	-	4.3	1.92	8.7	2.13
	5.1	-	-	-	-	4.0	1.76	8.3	2.02
Chlor-	0.005	8.0	3.13	8.0	3.13	4.7	2.02	7.0	2.13
sulfuron	0.025	6.3	3.10	8.0	3.09	4.3	1.78	7.3	2.02
Pentano-	2.2	8.0	3.09	8.0	3.16	6.7	1.99	8.3	2.10
chlor	6.6	8.0	3.12	8.0	3.10	6.0	1.99	7.3	2.12
Alloxydim	1.5	-	-	-	-	9.0	2.08	9.0	2.13
sodium	4.5	-	-	-	-	9.0	2.11	9.0	2.19
Fluazifop	0.75	-	-	-	-	9.0	2.19	9.0	2.09
-butyl	2.25	-	-	-	-	9.0	2.13	9.0	2.15
Sethoxydim	0.75	-	-	-	-	9.0	2.08	9.0	2.15
	2.25	-	-	-	-	9.0	2.08	9.0	2.15
Benazolin	0.2	7.7	3.09	8.0	3.11	4.6	2.03	7.0	2.12
	0.6	6.3	3.16	7.7	3.12	4.0	2.03	7.0	2.06
Clopyralid	0.2	7.3	3.08	7.3	3.08	5.3	2.10	7.3	2.10
	0.6	5.7	3.06	6.7	3.08	4.7	2.09	7.0	2.08
Triclopyr	0.5	4.0	2.67	7.0	3.10	2.0	0.53	5.7	1.94
	1.5	2.3	1.58	7.0	3.06	1.0	0	5.3	1.81
Untreated		7.9	3.12	7.9	3.12	9.0	2.12	8.8	2.12
S.E. ± (treated v. untreated)		0.23	0.074	0.23	0.074	0.27	0.056	0.34	0.056

+, *, -, see Table 1.

Asulam (1.7 and 5.1 kg/ha) applied in April was very damaging as an overall spray but there were no adverse effects from directed application. Chlorsulfuron (0.005 and 0.025 kg/ha) as an overall spray was only damaging with the higher dose at bud burst but both doses caused severe damage with April application. Directed treatment at bud burst appeared to be safe but in April caused obvious leaf chlorosis which was outgrown. Pentanochlor (2.2 and 6.6 kg/ha) applied overall at bud burst had no adverse effect but April applications caused leaf damage. With directed treatments in April the higher dose caused damage to treated shoots which was outgrown.

Alloxydim sodium (1.5 and 4.5 kg/ha), fluazifop-butyl and sethoxydim (both at 0.75 and 2.25 kg/ha) were not damaging when applied overall in April. Benazolin, clopyralid and triclopyr all caused severe damage with overall sprays particularly in April while directed sprays apart from benazolin at bud burst also caused leaf symptoms with some translocation. Fresh weight was significantly reduced by all application of triclopyr except directed sprays at bud burst.

TABLE 3

The effect of overall (O) and directed (D) sprays of foliar acting herbicides applied to blackcurrants at bud burst (12 March) and first open flower (8 April) (Experiment 1)

Herbicide	Appl. date Dose (kg/ha)	Appl. Method	12 March Score+ 13 Apr	7 May	F.wt* 19 May	8 April Score+ 24 Apr	21 May	F.wt.* 28 May
Glypho	1.4	O	3.3	3.7	2.71	-	-	
sate	4.2	O	3.0	2.7	2.58	-	-	
"	1.4	D	7.0	6.7	3.11	7.7	4.7	1.79
	4.2	D	6.0	5.7	2.97	5.0	4.0	1.43
Paraquat	1.0	O	4.0	3.3	2.68	-	-	-
	3.0	O	2.7	3.0	2.15	-	-	-
"	1.0	D	7.0	7.3	3.07	6.0	6.0	2.08
	3.0	D	6.0	6.0	2.99	5.3	6.0	1.95
Diquat	1.0	O	5.0	5.3	3.07	-	-	-
	3.0	O	3.3	3.7	2.78	-	-	-
"	1.0	D	7.0	7.3	3.12	6.3	7.3	2.05
	3.0	D	7.0	6.7	3.06	5.7	6.0	1.92
Phenmed-	1.1	O	-	-	-	5.3	7.0	2.05
ipham	3.3	O	-	-	-	4.3	6.0	1.97
Phenmed-	1.1°	O	-	-	-	4.7	7.0	2.12
ipham	3.3°	O	-	-	-	4.7	6.0	1.97
Untreated			8.8	7.9	3.11	8.8	9.0	2.12
S.E. ±	(treated v untreated)		0.25	0.23	0.074	0.31	0.23	0.069

+, *, -, see Table 1. ° plus adjuvant oil, 5 l/ha

Glyphosate caused leaf damage even with directed sprays and shoot weight was reduced by all treatments except directed sprays in March (Table 3). Diquat (1.0 and 3.0 kg/ha) was less damaging than paraquat (1.0 and 3.0 kg/ha) in March or April. Phenmedipham (1.1 and 3.3 kg/ha) ± adjuvant oil (Actipron) applied overall in April caused severe necrosis of sprayed leaves which was gradually outgrown. Shoot weight was not reduced.

Experiment 2 Response to shoot treatments in summer

Most of the triazine herbicides caused chlorosis and necrosis of youngest expanded leaves at spraying but this was outgrown and, apart from cyanazine, there were no significant reductions in growth (Table 4).

TABLE 4

The effect of overall application of herbicides on 15 July on blackcurrants (Experiment 2)

Herbicide	Dose (kg/ha)	Vigour score (0-9) 14 Aug	Shoot fresh wt 19 Aug % untreated	Herbicide	Dose (kg/ha)	Vigour score (0-9) 14 Aug	Shoot fresh wt 19 Aug % untreated
Simazine	1.5	7.7	102	Pentan-	2.2	7.7	94
	4.5	7.2	97	ochlor	6.6	6.2	96
Atrazine	1.5	6.7	92	Glufos-	0.5	4.0	70
	4.5	6.5	102	inate	1.5	2.7	29
Cyanazine	1.5	6.7	92	Paraquat	1.0	2.0	17
	4.5	5.7	77		3.0	1.0	3
Trietazine	1.5	7.7	103	Clopyralid	0.2	6.0	98
+ simazine	4.5	7.5	98		0.6	4.2	76
Terbuthyl	1.5	7.7	99	Benazolin	0.2	4.5	94
-azine	4.5	6.7	96		0.6	3.0	83
Diuron	2.0	5.0	55	Bentazone	1.5	5.7	71
	6.0	3.5	29		4.5	4.2	48
Pyridate	1.0	7.0	103	Untreated		7.9	100*
	2.0	6.0	100				
AC 222293	1.0	7.0	109	S.E. ± (treated		0.21	5.4
	3.0	6.5	102	v untreated			

* actual value 179 g/plant

Diuron was more toxic than any of the triazine treatments. Pyridate and pentanochlor caused leaf necrosis after spraying but subsequent growth was normal. AC 222293 caused chlorosis of sprayed leaves but had no overall effect on growth. Glufosinate caused less damage to shoots than paraquat at equivalent doses but damage was still severe. Clopyralid at 0.2 kg/ha caused leaf and shoot distortion but no effect on shoot weight. The higher rate reduced growth significantly but was less damaging than benazolin at the same dose. Bentazone caused severe damage at both doses.

Experiment 3 Response to root application

Alloxydim, sethoxydim, fluazifop-butyl, oxadiazon, pendimethalin and pentanochlor caused no damage when applied to the sand even at the highest doses tested (Table 5). High doses of bentazone had little effect. The degree of damage from doses of asulam, ethofumesate, methazole, propyzamide and trietazine + simazine was similar to equivalent doses of simazine. Atrazine, cyanazine, desmetryne, terbuthylazine were more toxic than simazine but less toxic than diuron. Hexazinone was appreciably more toxic than diuron and chlorsulfuron was damaging at very small doses. Benazolin was less toxic than clopyralid at equivalent doses.

DISCUSSION

Evaluation of the activity of herbicides on perennial crops must take account of possible toxicity from both shoot and root uptake. Because of variable response in field experiments pot tests have been found useful for screening the activity of large numbers of herbicides in other perennial crops (Clay 1980). This method also gives economies in cost because of the minimal land use and the speed of response of the plants. The interpretation of the results must of course take into account a number of factors such as dose of herbicide required for weed control in comparison with standard safe herbicides, likely season of use, acceptability of crop damage and for sand culture tests, soil availability, mobility and persistence (Clay 1982).

TABLE 5

The effect of a range of doses of herbicides applied on 1 May to the roots of blackcurrants grown in sand culture (Experiment 3)

Herbicide	ED50 value* mg/pot	Herbicide	ED50 value* mg/pot
Simazine	1.87	Oxadiazon	> 32.4
Atrazine	0.63	Propyzamide	2.16
Cyanazine	0.92	Pentanochlor	> 32.4
Desmetryne	0.84	Asulam	2.03
Hexazinone	0.12	Chlorsulfuron	0.0002
Terbuthylazine	0.99	Bentazone	18.5
Trietazine + simazine	2.33	Clopyralid	0.49
Diuron	0.28	Benazolin	0.89
Methazole	1.88	Alloxydim	> 32.4
Pendimethalin	> 32.4	Sethoxydim	> 32.4
Ethofumesate	1.49	Fluazifop-butyl	> 32.4

* ED50 value (dose causing 50% growth inhibition) based on score of plant condition assessed 2 July

Pendimethalin was the safest residual herbicide tested having no recordable activity from root application and no adverse effect as an overall spray at a high dose in winter and spring. Subsequent field experiments have confirmed this tolerance (Clay, unpublished data) and there is now a recommendation for its use in blackcurrants. Spring applications of methazole were found to be much safer than diuron, a herbicide recommended for use in blackcurrants. Methazole was recommended for use in blackcurrants, in mixtures with simazine but it is no longer available commercially. Ethofumesate had no adverse effect on shoot weight but the leaf symptoms resulting from winter and spring use suggest unacceptable persistence of herbicide effects. Oxadiazon was included as a standard herbicide. The root activity test confirmed the absence of damage from root exposure found in other crops (Clay 1980) and the safety of dormant season treatment. The leaf necrosis and subsequent recovery in growth from later applications has also been found in field experiments (Clay, unpublished data). Similarly oxyfluorfen has caused severe leaf damage to young plants in both pot and field experiments which was subsequently outgrown. However this herbicide could find a use in dormant established blackcurrants since it controls weeds resistant to other herbicides. A number of triazine herbicides with some post-emergence activity on small weeds were tested with a view to use in spring. While shoot treatment with all except hexazinone was acceptably safe at bud burst the root activity tests indicated greater toxicity than simazine. However toxicity of most was less than diuron, a recommended herbicide, suggesting that field application could be safe. Trietazine + simazine was found to be the least toxic of this group but, after bud burst, only directed application would be likely to be safe. Pentanochlor is a post-emergence herbicide recommended as a directed spray. This was relatively safe compared with the other post-emergence broad-leaf weed herbicides tested although bentazone appeared safe as a spray at bud burst and showed little activity from root application. However its activity as a herbicide would not be great early in the spring. Shoot treatments with chlorsulfuron caused similar symptoms and degree of toxicity to asulam and was relatively safe as a directed spray. However it was much more toxic as a root application, even allowing for the very low dose required.

All three selective grass-weed killers tested were safe whether applied to roots or shoots and this has been confirmed by field experiments (Plowman et al 1980). However fluazifop-butyl has caused damage on another blackcurrant cultivar (Lawson et al 1984) indicating the need to check on varietal tolerance even with outstandingly safe herbicides. Blackcurrants showed good recovery from overall and directed spray with clopyralid at 0.2 kg/ha. This has been confirmed in field trials (Clay, unpublished data) and the herbicide is now recommended for directed use. Triclopyr was very toxic except as a directed spray at bud burst. A herbicide with this toxicity could only be useful for careful spot-treatment of otherwise intractable weeds. Glyphosate was very toxic when applied as an overall spray in March or a directed spray in April, confirming earlier field studies (Stott et al 1974). Paraquat was safer but more toxic than glufosinate as an overall spray in summer. This latter difference may have been less if the test had continued longer. Phenmedipham, AC 222293 and pyridate all caused noticeable necrosis or chlorosis of sprayed leaves but symptoms were subsequently outgrown. Their use could only be considered in the crop to control otherwise resistant weeds.

ACKNOWLEDGEMENTS

Thanks are due to the herbicide manufacturers for the supply of experimental herbicides and to the staff of the former Weed Research Organization for assistance with the experimental and statistical work.

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EVALUATION OF GLUFOSINATE-AMMONIUM AND PACLOBUTRAZOL FOR CONTROL OF CANE VIGOUR IN RASPBERRY

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ABSTRACT

Glufosinate-ammonium desiccated the first flush of young canes much more slowly than the standard dinoseb-in-oil, even at three times the suggested rate of 0.6 kg a.i./ha. There was evidence of translocation up the fruiting cane and into the stool, particularly at the higher rate. Since cane vigour control depends on rapid contact kill without translocation or residual effects, glufosinate-ammonium is not considered suitable for this technique.

Paclobutrazol applied as a growth retardant at 0.25 kg a.i./ha had no useful effect on young canes. Results with 0.75 kg a.i./ha were variable, with some canes temporarily retarded and others not; records on total cane length showed overall results similar to dinoseb-in-oil. More new canes were produced in the following year on these plots, in the absence of further treatment, than grew on totally untreated plots. There was no evidence of residual activity on cane heights in the second year. The variable effects on treated canes plus restrictions currently applicable to use in tree fruits suggest that paclobutrazol has little scope for use in cane management.

INTRODUCTION

Dinoseb-in-oil is widely used in raspberry plantations in the United Kingdom to remove the first flush of vegetative canes of very vigorous cultivars such as Glen Clova (Lawson & Wiseman 1981). Dinoseb is however subject to regulations made under the Poisons Act 1972 and is unpleasant to apply. New contact herbicides and desiccants which show promise for arable crops are therefore routinely screened at SCRI as possible alternatives to dinoseb-in-oil for cane desiccation. Many less vigorous cultivars do not produce adequate replacement growth following cane desiccation, but could nevertheless benefit from a reduction in the height of young canes and the concentration of a greater proportion of cropping nodes below tipping height. This would be best achieved by the temporary regulation of the growth of first-flush canes.

Glufosinate-ammonium (HOE 39866) appeared promising as a desiccant treatment in a preliminary screening experiment (Lawson & Wiseman 1983), while paclobutrazol (PP333) has proved successful in reducing vegetative growth in tree fruits (Anon. 1983). Both chemicals were examined over two growing seasons in an established raspberry plantation, to evaluate their effects on cane and fruit production in comparison with the standard dinoseb-in-oil.

MATERIALS AND METHODS

The experiment was carried out at Invergowrie in a plantation of raspberry cv Malling Jewel planted in 1974. Plots consisted of single rows 6.6 m long, each of 11 stools. Rows were 1.8 m apart. Plots were arranged in randomised blocks with three replicates. Four untreated plots were included in each replicate. Experimental treatments were applied by an Oxford Precision Sprayer, using fan jets, to 30 cm bands on either side of the centre of the crop row, when young canes were 10-15 cm tall. All raspberry foliage below 45 cm, whether fruiting laterals or young canes, was sprayed using a water volume of 1000 l/ha (sprayed) to ensure thorough wetting. Application was made to all treated plots on 18 May 1983 and repeated on half the plots on 8 May 1984; the half not treated in 1984 will be termed resting plots.

Treatment	Dilution of formulated product in water	kg a.i./ha
Dinoseb-in-oil	1.0%	2.50
Glufosinate-ammonium	0.3%	0.60
	0.9%	1.80
Paclobutrazol	0.3%	0.25
	1.0%	0.75

Records of cane and fruit production were co-varied on a uniformity assessment made prior to the first treatment, to allow for the considerable plot-to-plot variability typical of a plantation of this age. The plantation was managed without soil cultivation. Weeds were controlled by annual application of bromacil at 1.1 kg a.i./ha in March. Raspberry suckers growing between stools and in the alleys were mechanically removed twice between late April and early July.

RESULTS

In both years, treatment with dinoseb-in-oil completely desiccated all young vegetative canes within a few days of application. Glufosinate-ammonium at the lower rate took two weeks to kill treated leaves, and it was another two weeks before the treated stems turned black and died. Replacement canes emerged later than on plots treated with dinoseb-in-oil, but showed no visible evidence of malformation or stunting. At the higher rate, desiccation occurred more rapidly, although still taking several weeks to reach completion. Replacement canes were very slow to emerge, but appeared normal. Paclobutrazol at the lower rate had no visible effect on sprayed canes in either year, but the higher rate retarded growth of a proportion of the treated canes for one-three weeks, after which they started to grow actively again. Other canes, often immediately adjacent, were apparently unaffected; so were the few canes emerging after treatment. Canes which had been retarded temporarily with paclobutrazol had shorter than normal internode distances for 5-8 cm above the height at which they were sprayed. Rate of cane emergence and growth on plots given no repeat treatment in 1984 were apparently normal, with no visible evidence of malformation or retardation.

No chemical treatment significantly increased or decreased yield of fruit in 1983, although they all improved mean berry weight. Both rates of glufosinate-ammonium decreased numbers of berries produced per metre of fruiting cane (Table 1).

The lower rate of paclobutrazol had no effect on any aspect of cane production recorded at the end of the 1983 growing season (Table 2). Glufosinate-ammonium, especially at the higher rate, reduced cane numbers as well as mean height. Dinoseb-in-oil and the higher rate of paclobutrazol

TABLE 1

1983 Fruit production cv Malling Jewel

Treatment	Dose kg a.i./ha	Yield t/ha	Berries/m of cane	Mean wt g/100 berries
Untreated		9.7	72.4	229
S.E. mean ±		0.28	1.67	3.9
Dinoseb	2.50	10.0	69.4	247*
Glufosinate	0.60	9.5	63.6**	258***
	1.80	9.2	59.0***	265***
Paclobutrazol	0.25	10.5	73.4	243*
	0.75	10.1	69.2	249**
S.E. mean ±		0.40	2.36	5.5

TABLE 2

1983 Cane production cv Malling Jewel

Treatment	Dose kg a.i./ha	Total cane length m/plot		No. canes produced/ plot	Mean ht/ cane (cm)
		Produced	Retained≠		
Untreated		107.6	83.7	83.7	128
S.E. mean ±		3.30	3.38	2.31	2.4
Dinoseb	2.50	85.6***	58.9***	77.9	111***
Glufosinate	0.60	80.3***	53.6***	73.6*	109***
	1.80	59.5***	38.4***	60.3***	98***
Paclobutrazol	0.25	109.6	80.9	90.1	122
	0.75	92.1**	61.7***	84.1	108***
S.E. mean ±		4.47	4.78	3.26	3.4

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

≠ after removing short (<65 cm) and broken canes and tipping tall canes at 150 cm.

TABLE 3

1984 Fruit production cv Malling Jewel

Treatment	Dose kg a.i./ha	Years treated	Yield t/ha	Berries/m of cane	Mean wt g/100 berries
Untreated		83+84	10.2	68.4	230
S.E. mean ±			0.47	3.42	7.0
Dinoseb	2.50	83	10.5	86.1*	269*
		83+84	10.2	88.0*	250
Glufosinate	0.60	83	8.9	79.8	255
		83+84	9.5	92.4**	272*
	1.80	83	8.5	99.3***	288**
		83+84	8.1	94.1**	299***
Paclobutrazol	0.25	83	10.7	76.4	226
		83+84	10.6	71.9	237
	0.75	83	9.5	90.8**	214
		83+84	9.2	85.7*	241
S.E. mean ±			0.94	6.85	14.0

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

produced similar results in terms of reducing cane production, despite the different methods of achieving it. The percentage of total cane production retained for fruiting ranged from 75% on untreated plots and those given the lower rate of paclobutrazol to 64-70% on other plots.

Resting plots in 1984 showed no significant differences between experimental treatments in terms of total yield of fruit (Table 3). Berry numbers per metre of cane were greater in plots originally treated with dinoseb-in-oil and the higher rates of glufosinate-ammonium and paclobutrazol than on untreated plots. The first two treatments also increased mean berry weight, but all these effects were offset by the reduced length of fruiting cane tied in. Repeating the initial treatments in 1984 had relatively little effect on fruit production in comparison with equivalent rested plots. Glufosinate-ammonium at the lower rate was the only treatment to increase both numbers of berries and mean berry weight.

Cane production on resting plots originally treated with dinoseb-in-oil or the lower rate of glufosinate-ammonium showed no residual effects of 1983 applications (Table 4); cane numbers and therefore total length/plot were, however, substantially lower on plots treated only in 1983 with the higher rate of glufosinate-ammonium, in comparison with totally untreated plots. In contrast, cane numbers were significantly increased on plots given either rate of paclobutrazol in 1983 and rested in 1984. Repeat treatment with glufosinate-ammonium, especially at the higher rate, was more detrimental to cane production than equivalent treatment with dinoseb-in-oil. Neither rate of paclobutrazol significantly reduced cane numbers, mean height or the proportion of taller canes in comparison with those on untreated plots. The plantation was ploughed in after end-of-season cane records were completed.

DISCUSSION

This was an old plantation of Malling Jewel, still producing respectable yields, but not one which would be expected to respond positively to techniques for controlling cane vigour. In addition the experiment was carried out in two years when very dry summers occurred and cane heights were below average even on untreated plots. The primary objective was, however, to evaluate the performance of the new chemicals against that of dinoseb-in-oil, to determine whether or not they merited inclusion in a longer-term cane management experiment on a younger and much more vigorous plantation. The results suggest that neither glufosinate-ammonium nor paclobutrazol meet the necessary requirements, for the reasons outlined below.

The reductions in berry numbers per metre of fruiting cane in 1983 with both rates of glufosinate-ammonium indicate possible translocation up the fruiting canes from lower sprayed laterals; the significant reductions in replacement cane numbers recorded following treatment in 1983 or 1984 also suggest translocation from treated canes into the stool. Dinoseb-in-oil acts purely by contact effect and gives results comparable to those achieved by cutting and removing first-flush canes (Lawson 1980). Translocation up the fruiting cane or into the stool is undesirable, while slow desiccation does not encourage rapid emergence of replacement canes. In addition there was a clear dose response to treatment with glufosinate-ammonium, the higher rate giving the more rapid and effective desiccation, but also the greater suppression of replacement canes. There would, therefore, be little margin of safety for accidental overdosing. Experiments at SCRI on seed potato

TABLE 4

1984 Cane production cv Malling Jewel

Treatment	Dose kg a.i./ha	Years treated	Total cane length (m) produced/ plot	No. canes/ plot	Mean ht/ cane (cm)	% no. canes >120 cm tall
Untreated		83+84	98.6	85.6	116	52
S.E. mean ±			3.23	2.82	2.5	3.4
Dinoseb	2.50	83	90.1	72.9	124	63
		83+84	83.3*	73.1	116	53
Glufosinate	0.60	83	101.6	83.5	123	51
		83+84	78.4*	67.7**	116	53
	1.80	83	78.8*	66.9**	118	48
		83+84	55.9***	49.5***	112	47
Paclobutrazol	0.25	83	123.8**	101.7*	122	63
		83+84	101.2	88.3	115	52
	0.75	83	117.5*	101.1*	116	49
		83+84	84.5	74.8	113	41
S.E. mean ±			6.46	5.64	5.0	6.9

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

crops have shown that glufosinate-ammonium applied as a desiccant pre-harvest is translocated from foliage to tubers and retards the growth of these tubers when replanted, again with an increased severity at higher doses (Lawson & Wiseman 1984). The slowness of desiccation in raspberry, the evidence of translocation in this and other crops and the marked dose response effectively rule out this chemical as an alternative to dinoseb-in-oil for cane vigour control. It may be worth further investigation as a directed treatment for the control of raspberry suckers growing in the alleys between rows, where a degree of translocation combined with slower desiccation could possibly suppress regrowth more effectively than is possible with the purely contact effect of dinoseb-in-oil.

Paclobutrazol at the lower rate had no effect on the growth or final height of treated canes in 1983 or 1984. At the higher rate, the overall effect on yield components and cane production of treatment in 1983 and in 1984 was fairly similar to that of dinoseb-in-oil, considering the quite different methods employed to reduce cane vigour.

The major drawback with paclobutrazol at this rate was the variation in response between individual canes within the stool, some showing marked retardation, others being apparently unaffected. More even effects are necessary if picker access is to be improved and the amount of tipping of canes required in winter is to be reduced. A higher rate or later application might give more uniform results, but recent recommendations for this chemical on tree fruits (Anon. 1984) state that the upper limit of dosage in any one season is 0.75-1.00 kg a.i./ha and that final treatment should not take place within six weeks of harvest. If these restrictions were applied to raspberry, there would be little latitude to alter dose or timing beyond those used in our experiment. Additionally the tree fruit recommendations suggest that residual activity of paclobutrazol may reduce vegetative growth in the year after treatment. This apparently conflicts with our record of increased raspberry cane numbers when plots treated at either rate in 1983 were rested in 1984. Finally, removal of the first flush of vegetative canes with dinoseb-in-oil alters the phasing of cane growth in relation to several pest and diseases; replacement canes are less vulnerable to attack (Lawson 1980). Retardation of growth of first flush canes may not have the same benefits, particularly if the effect varies from cane to cane within the stool. This drawback would apply with any growth regulator, but given the high rate needed to produce the moderate degree of overall cane retardation obtained, the uneven effect on individual canes at this rate, restrictions on timing and the increase rather than the expected decrease in growth of the following season's young canes, it does not appear that paclobutrazol offers the clear and positive advantages in controlling vegetative growth in raspberry plantations that it does in tree fruit orchards. Much more precise information on its activity in raspberry would be needed before the inclusion of paclobutrazol in long-term experiments on any other aspect of growth regulation in this crop could be justified.

ACKNOWLEDGEMENTS

Our thanks are due to R. Wilson and Mrs G. Wright for technical assistance and to Hoechst UK Ltd and Plant Protection Division ICI Plc for the supply of experimental samples.

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EVALUATION OF GLUFOSINATE-AMMONIUM FOR RUNNER CONTROL IN STRAWBERRIES

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ABSTRACT

Glufosinate-ammonium was evaluated as a possible alternative to dinoseb-in-oil or paraquat for the control of unwanted strawberry runners. It acted more slowly than the standard herbicides, but achieved comparable levels of control and showed no adverse effects on the growth or yield of the cropping rows. Further examination of this potential use is recommended.

INTRODUCTION

Paraquat and dinoseb-in-oil are currently widely-used in the United Kingdom for the chemical control of unwanted strawberry runners. These chemicals, while highly effective, have disadvantages in that they are both subject to regulations made under the Poisons Act 1972, dinoseb-in-oil is unpleasant to apply, and paraquat occasionally causes injury to cropping rows by translocation from treated runners. New contact herbicides or desiccants which show promise for arable crops are therefore routinely screened at SCRI for possible use in strawberry runner control. This paper reports a series of preliminary experiments with glufosinate-ammonium (HOE 39866) recently developed by Hoechst and currently being evaluated both as a desiccant and as a contact herbicide (Anon. 1982).

MATERIALS AND METHODS

Four experiments were carried out at Invergowrie between 1982 and 1984 in four-year-old matted row plantations of cv Cambridge Favourite. The matted rows were 60 cm wide and the alleys between them were 30 cm wide. Runners were allowed to root freely in the alleys during the summer months and runner connections were not severed before spray application. In the screening trials, plots consisted of single alleys 6.75 m long by 30 cm wide between two matted rows and records were confined to regular scores of foliage desiccation (0 = unaffected, 10 = 100% foliage kill), together with observations on speed of recovery and on any spread of herbicide effects into the adjacent matted rows. In the fourth experiment, each plot comprised two matted rows and three treated alleys 6.75 m long, to allow assessment of possible effects on fruit production; records were taken of yield, fruit size and quality.

In all four experiments spray drift to the adjacent matted rows was prevented by means of weighted plastic shields placed over the crop row immediately before spraying and removed thereafter. Spray reaching the shields was channelled to the end of the plot, via guttering. Treatments were applied by Oxford Precision Sprayer using fan jet nozzles at 276 kPa pressure in 1000 l water/sprayed ha. Rates of application of individual herbicides and timing of treatment are shown in Tables 1-5. All plots were treated once only and were arranged in randomised blocks with either three or four replicates.

RESULTS

Expt I

Treatments were applied in warm sunny conditions in early May. Dinoseb-in-oil achieved virtually complete desiccation within 6 days while glufosinate-ammonium was slow to take effect, needing over 7 weeks to reach the same degree of desiccation (Table 1). Neither herbicides showed visible evidence of translocation into adjacent matted rows. New runner leaves were appearing on plots treated with dinoseb-in-oil several weeks before regrowth commenced in plots treated with glufosinate-ammonium. The plantation was ploughed up in August.

TABLE 1

Expt I (1982) Desiccation scores (0-10)

Treatment (6 May)	kg a.i./ha	12 May	20 May	31 May	14 June
Dinoseb-in-oil	2.5	9.5	9.5	9.5	9.5
Glufosinate	0.6	0.5	4.5	6.5	9.5

Expt II

Treatments were applied in cold damp weather, followed shortly afterwards by a heavy rain shower. Nevertheless paraquat gave rapid and effective desiccation of all treated foliage (Table 2). Dinoseb-in-oil took considerably longer but eventually achieved comparable results. Glufosinate-ammonium was very slow-acting, taking six weeks to reach its maximum effect, showing relatively little response to increases in rate of application and failing to achieve as high a degree of foliage kill as the other two herbicides. There was no visible evidence of translocation into cropping rows by any herbicide treatment and no regrowth had occurred by the time the plantation was ploughed up in early January.

TABLE 2

Expt II (1982) Desiccation scores (0-10)

Treatment (5 Nov.)	kg a.i./ha	15 Nov.	29 Nov.	7 Dec.	20 Dec.
Dinoseb-in-oil	2.5	5.0	8.8	9.1	9.6
Paraquat	1.1	9.3	10.0	10.0	10.0
Glufosinate	0.6	0.4	6.8	8.1	8.6
	0.9	0.3	5.8	7.4	8.4
	1.2	0.4	7.3	8.4	8.9

Expt III

This experiment was identical to Expt II but was sprayed 6 days later and was followed by several days dry, but cold weather. Dinoseb-in-oil and paraquat performed very much the same as in the previous experiment, but glufosinate-ammonium achieved a higher final level of desiccation and there was a slightly greater response to increased dosage. Little or no natural senescence had occurred by 20 December in this or the above experiment. No regrowth had occurred on any treated plot by the end of December.

TABLE 3

Expt III (1982) Desiccation scores (0-10)

Treatment (11 Nov.)	kg/a.i./ha	15 Nov.	29 Nov.	7 Dec.	20 Dec.
Dinoseb-in-oil	2.5	4.5	9.5	9.8	9.8
Paraquat	1.1	9.4	10.0	10.0	10.0
Glufosinate	0.6	0.1	5.8	8.6	9.4
	0.9	0.1	7.4	9.1	9.6
	1.2	0.4	8.0	9.4	10.0

<u>Expt IV</u>

Both applications were made in dry sunny weather. Paraquat gave rapid and very effective desiccation whether applied in the autumn or the spring (Tables 4 and 5). Glufosinate-ammonium was slower-acting in both seasons but eventually achieved almost complete kill of treated foliage, helped in early winter by natural senescence due to a succession of hard frosts. Records on ground cover by runner foliage in mid May showed both herbicides maintaining equally effective suppression regardless of season or treatment. Runner plants were cut and removed from untreated alleys on 15 May, to avoid any competition with fruiting rows.

TABLE 4

Expt IV Autumn application (1983). Desiccation scores and spring regrowth

Treatment (7 Oct.)	Desiccation (0-10)					% cover
	kg a.i./ha	13 Oct.	27 Oct.	21 Nov.	5 Dec.	15 May
Untreated		0	0	0	2.6	21
Paraquat	1.1	8.0	9.8	9.8	9.8	<1
Glufosinate	1.0	0	6.1	7.9	9.1	2

TABLE 5

Expt IV Spring application (1984). Desiccation scores and spring regrowth

Treatment (25 Apr.)	Desiccation (0-10)					% cover
	kg a.i./ha	27 Apr.	30 Apr.	8 May	15 May	15 May
Untreated		0	0	0	0	21
Paraquat	1.1	5.0	8.5	9.3	9.4	<1
Glufosinate	1.0	0	2.3	9.4	9.8	<1

There was no evidence of translocation into fruiting rows by either herbicide and yield results (Table 6) gave no indication of adverse effects of paraquat or glufosinate-ammonium whether applied in autumn or spring. Low numbers of berries per crown reflected the presence of a high percentage of small unproductive crowns in the matted row. Despite this, yields were acceptably high for a plantation in its fifth cropping year.

TABLE 6

Expt IV Yield records (1984) cv Cambridge Favourite

Treatment	kg a.i./ha	Yield t/ha	Mean berry wt(g)	Berries/ 10 crowns
Untreated		11.2	14.3	17.4
S.E. mean ±		0.86	0.49	1.06
Paraquat (autumn)	1.1	10.4	15.2	15.8
Glufosinate (autumn)	1.0	11.6	15.7	17.3
Paraquat (spring)	1.1	13.2	15.7	20.0
Glufosinate (spring)	1.0	11.8	14.8	18.2
S.E. mean ±		1.21	0.69	1.50
Sig. of effects				
Paraquat v glufosinate		NS	NS	NS
Spring v autumn		NS	NS	NS

DISCUSSION

Dinoseb-in-oil and paraquat applied at rates recommended for runner control performed satisfactorily and their relative speed of desiccation under different weather conditions was similar to that reported in earlier experiments by Lawson & Wiseman (1980). Glufosinate-ammonium was much slower-acting than either of the standard chemicals, regardless of dose or weather conditions, but it eventually gave acceptable and usually comparable results. Evidence from Expt III suggested that increasing the dosage speeded up the rate of desiccation and slightly improved the final result. This was not as evident in Expt II where rain shortly after application may have impaired activity. More work is needed to confirm the most reliable dosage to suit varying weather and crop conditions, but both autumn and spring application at 1 kg a.i./ha were as effective as the standard rate of paraquat. Evidence from similar research on raspberry (Lawson & Wiseman 1983, 1985) confirms the much slower, but eventually equally effective activity of this herbicide in comparison with dinoseb-in-oil.

In none of the current experiments were weather conditions at and after application conducive to translocation of paraquat from treated runners to the adjacent matted row. It was therefore not possible to determine whether glufosinate-ammonium behaves similarly, although there was no evidence that this herbicide translocates in conditions where paraquat does not. However, suppression of regrowth by treated runners appeared to be more persistent with glufosinate-ammonium than with dinoseb-in-oil and more comparable with the activity of paraquat (Lawson & Wiseman 1980), which suggests that some degree of translocation from foliage to runner crowns may take place. Experiments on potato have shown that glufosinate-ammonium applied as a desiccant pre-harvest can translocate from foliage to tubers (Lawson & Wiseman 1984). It may therefore be advisable to make recommendations for discing along the crop rows prior to treatment, similar to those currently advocated with paraquat, until information is available from application in seasons where paraquat causes damage.

More information is needed on dose and spray volume in relation to crop density and on the persistence of suppression of treated runner plants. However, if glufosinate-ammonium finds markets in the United Kingdom for use in major arable crops and growers will accept its relatively slow speed of action, it should be considered for further development as a strawberry runner desiccant.

ACKNOWLEDGEMENTS

We thank R.N. Wilson and Mrs G. Wright for technical assistance and Hoechst UK Ltd. for providing experimental samples of glufosinate-ammonium.

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FURTHER EXPERIMENTS ON THE CONTROL OF EPILOBIUM CILIATUM WITH HERBICIDES

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ABSTRACT

A number of herbicides recommended in fruit crops were tested for control of *E. ciliatum* in experiments at three sites. Diphenamid (4.5 kg/ha), napropamide (4.5 kg/ha), oxadiazon (1 kg/ha), oxyfluorfen (1 kg/ha) and propyzamide (1.6 kg/ha) applied in winter gave effective pre-emergence control but when applied to established *E. ciliatum*, only oxadiazon and oxyfluorfen in spring were effective. Norflurazon (4.5 kg/ha) was effective on established plants in winter and spring but paraquat + diquat (1.1 kg/ha) was generally ineffective. 2,4-D amine in spring killed the weed. Clopyralid (0.2 kg/ha) severely stunted the weed at all application dates from December to May. Clopyralid activity in May was increased by repeated treatment of 0.1 kg/ha mixed with phenmedipham (0.55 kg/ha) at a 5 day interval. Post-emergence control with chloroxuron (4.5 kg/ha) in May was improved by addition of wetter and application as a split dose at a 5 day interval.

INTRODUCTION

Epilobium ciliatum (American willowherb) has become a serious problem in perennial crops grown without soil disturbance, where simazine has been used repeatedly. Seed from such plants has been shown to be resistant to simazine applied pre-emergence compared with other *Epilobium* species (Bailey & Hoogland, 1984) although it was susceptible to other soil-acting herbicides. Diuron gives effective control of *E. ciliatum* both pre- and post-emergence in top and bush fruit but other effective herbicides are needed particularly for strawberries. A number of soil and foliar-acting herbicides selective in fruit crops were tested in field experiments on established and seedling *E. ciliatum* at sites at Tiptree, Essex; Norwich, Norfolk and Begbroke, Oxford. At the third site a number of non-selective herbicides were also evaluated.

MATERIALS AND METHODS

Details of plant material, plot size, replication and spraying for the six experiments are given in Table 1. The herbicide treatments are shown in Tables 2-7 the formulations commercially available in the UK being used. Where wetter was added it was non-ionic (Agral).Adjuvant oil as Actipron was used in Experiment 3.

Experiment 1

Plots were laid out in established blackcurrants at Tiptree Essex, 1 m^2 either side of the bush row being sprayed. The *E. ciliatum* was present mainly as rosettes at the base of the previous seasons flowering shoots, with few seedlings present. Herbicides were applied on 25 October 1983 with a pressurized knapsack sprayer. Plant no./plot was recorded on 31 May 1984.

* present address: Dale End, Kirkbymoorside, N. Yorkshire

TABLE 1

Details of the experiments at the different sites

Site	Expt No.	Plant material	Plot size (m)	Replication	Spray dates	Tee Jet No.	Vol. rate (l/ha)
Tiptree	1	Natural population	2 x 2	3	25 Oct. 83	6502	370
Norwich	2	Natural population	5 x 2	3	29 Nov. 83 4 Apr. 84	6502	330
Begbroke	3	Transplanted October 83	1 x 1	6	3 May 84	6502	373
Begbroke	4	Transplanted October 83	1 x 1	2	3,18 May 84	6502	373
Begbroke	5	Transplanted October 84	1 x 1	2	18 Dec. 84 27 Mar. 85 19 Apr. 85 16 May 85	8003 " " 	330 " "
Begbroke	6	Natural population	2 x 1	3	19,24 Apr. 16 May 85	6502 "	240 "

Experiment 2

Plots were laid out in established strawberries at Tunstead, Norwich, a 5 m length of two adjacent rows being treated. At spraying on 29 November large numbers of rosettes and seedlings were present both with 4 to 10 leaves. At spraying on 4 April overwintered plants were similar in size and appearance to the previous spray date but there were also large numbers of cotyledon stage seedlings. On 31 May vigour and % cover of seedlings was assessed and vigour and no./plot of overwintered rosettes.

Experiments 3 and 4

Single plants of Epilobium ciliatum grown from seed from a simazine resistant population were planted in a sandy loam soil at Begbroke Hill, Oxford in October 1983, 20 cm apart in single rows. Herbicides were applied using a hand-held pressurized sprayer when the plants were tillering and main shoot height was 10-15 cm (3 May) and 15-20 cm (18 May). Vigour was scored at intervals on a 0-9 scale (0 = dead, 9 = healthiest untreated plants) and fresh weight of shoots/plot recorded at the end of the experiment.

Experiment 5

The site, plant source and arrangement and spraying method were the same as experiments 3 and 4, transplanting being done in October 1984. At spraying in December plant rosettes were 5 to 7 cm high and up to 10 cm diam. On 27 March height was approximately 7 cm and growth was just beginning. On 19 April plants were 7 to 12 cm high with extension growth beginning. On 16 May plants were about 20 cm high, growing vigorously and tillering. Plant vigour was recorded at intervals and maximum shoot height and shoot fresh weight/plot at the end of the experiment.

Experiment 6

Treatments were applied to a natural population of E. ciliatum developing from seed in an area where simazine-resistant plants had been grown the previous year. At the first spraying date (19 April) plants were mainly 5 to 8 cm high, some were tillering and extension growth was just beginning. At the 16 May application spray date plants were 7 to 20 cm tall and growing vigorously. Assessments were the same as in the previous experiment but final number of plants/plot was also recorded.

RESULTS

Experiment 1

Simazine (2.0 kg/ha) chlorthal-dimethyl (6.0 kg/ha) and propachlor (4.0 kg/ha) applied in October had no effect on the numbers of *E. ciliatum* plants recorded in May (Table 2). Most of the plants present were spring germinated seedlings. Lenacil (2.0 kg/ha), propyzamide (1.7 kg/ha) and diuron (0.9 kg/ha) reduced plant numbers by 85% compared with the control but diuron (0.5 kg/ha) was less effective. There was no weed on plots treated with oxadiazon (1.0 kg/ha) and oxyfluorfen (1.0 kg/ha).

TABLE 2

The effect of herbicide treatments applied on 25 October on number of *E. ciliatum* (Experiment 1)

Herbicide	Dose (kg/ha)	No./plot 31 May	Herbicide	Dose (kg/ha)	No./plot. 31 May
Simazine s.c	2.0	38	Propachlor s.c	4.0	43
Propyzamide	1.7	3	Chlorthal-dimethyl w.p	6.0	29
Diuron w.p	0.5	22	Oxadiazon	1.0	0
Diuron w.p	0.9	4	Oxyfluorfen*	1.0	0
Lenacil	2.0	6	Untreated control		35

* 24% e.c.

Experiment 2

Application of chloroxuron (4.5 kg/ha) in late November or early April reduced numbers of rosettes present the following May but seedling numbers and vigour of surviving plants was unaffected (Table 3). Addition of adjuvant oil to chloroxuron applied in April led to complete kill of seedlings and increased kill of overwintering rosettes. With other November treatments, diphenamid (4.5 kg/ha) reduced vigour but not number of overwintering plants and reduced vigour and % count of seedlings in spring. Ethofumesate (2.0 kg/ha), propachlor s.c. and w.p. (4.5 kg/ha) and terbacil (0.6 kg/ha) had no measurable effect when recorded in May. Simazine (0.5 kg/ha) ± propyzamide (0.5 kg/ha), propachlor + chlorthal dimethyl (6.0 kg/ha) slightly reduced growth of seedlings the following year. Napropamide had some inhibitory effect on rosette growth at 1.4 kg/ha, higher rates reduced number and vigour of survivors, and all rates gave almost complete control of seedlings in spring. With treatments on 4 April clopyralid (0.2 kg/ha) ± phenmedipham (1.1 kg/ha) gave complete kill of overwintered rosettes and seedlings; phenmedipham alone had no effect on overwintered plants but reduced ground cover of seedlings considerably.

Experiment 3

Clopyralid (0.2 kg/ha) applied on 3 May to actively growing plants severely stunted but did not kill the plants (Table 4). There was little or no increase in activity with added wetter or adjuvant oil. Chloroxuron (4.5 kg/ha) checked growth but recovery was rapid. Addition of adjuvant oil slightly increased the initial effect but had no long term effect. Added wetter (0.5% spray solution) had greater effect which was not outgrown

TABLE 3

The effect of herbicide treatments applied to E. ciliatum in strawberries in winter and spring, assessed on 31 May (Experiment 2)

Herbicide	Dose (kg/ha)	Appln. date	Seedlings Vigour (0-9)	Seedlings % cover	Overwintered rosettes Vigour (0-9)	Overwintered rosettes No/plot
Chloroxuron	4.5	29 Nov.	9.0	7	9.0	39
Diphenamid	4.5	"	5.0	25	4.3	53
Ethofumesate	2.0	"	9.0	30	9.0	63
Propachlor w.p.	4.5	"	9.0	47	9.0	86
Propachlor s.c.	4.3	"	9.0	53	9.0	60
Terbacil	0.6	"	9.0	43	9.0	76
Napropamide	1.4	"	4.7	4	7.3	42
"	2.7	"	2.3	4	4.7	30
"	4.0	"	2.0	2	3.7	14
Propachlor + C*	4.3	"	6.3	28	8.3	94
Simazine	0.5	"	8.0	29	8.3	41
Simazine + propyzamide	0.5 0.5	"	9.0	38	9.0	63
Chloroxuron	3.0	4 April	8.0	4	9.0	41
Chloroxuron	4.5	"	9.0	1	9.0	10
Chloroxuron O+	4.5	"	0	0	6.0	7
Clopyralid	0.2	"	0	0	0	0
Phenmedipham	1.1	"	8.3	8	8.3	63
Untreated			9.0	53	9.0	78
SE±			0.75	7.2	0.84	12.9

* propachlor s.c. + chlorthal-dimethyl 6.0 kg/ha. +O, plus oil 5 l/ha

although plants survived to produce flowers. 2,4-D amine (2.0 kg/ha) killed all treated plants. Diuron (0.5 kg/ha) checked growth temporarily but regrowth was rapid. The 1.0 kg/ha rate gave long-term check although surviving plants flowered. Diphenamid (4.5 kg/ha) stunted plants after application but plants recovered. Paraquat + diquat caused severe leaf necrosis after treatment but plants regrew strongly and flowered.

Experiment 4

Applying clopyralid (0.2 kg/ha) and chloroxuron (4.5 kg/ha) as split doses at a 15 day interval either alone or in mixture generally failed to increase toxicity to E. ciliatum (Table 5). The least effect was given by half-doses of the chemicals applied alone or in mixture on 3 May. Chloroxuron (2.25 kg) followed by clopyralid (0.1 kg/ha) gave an effect similar to a single full dose of clopyralid but clopyralid (0.1 kg) followed by chloroxuron (2.25 kg/ha) was virtually no more effective than the clopyralid alone (data not shown).

Experiment 5

Diphenamid and napropamide applied to established plants of E. ciliatum in December led to stunting of growth particularly at high doses but no plants were killed and growth later in spring was vigorous (Table 6). Diphenamid was more effective than napropamide. Spring applications of these herbicides were slightly more effective when assessed in June.

these herbicides were slightly more effective when assessed in June. Propyzamide applied in December resulted in long-term stunting of growth but regrowth from the 0.8 kg/ha rate was vigorous. Pyridate applied in December only had a slight depressing effect on subsequent growth but mixture with simazine markedly improved control although some plants grew vigorously (data not shown). Norflurazon (4 kg/ha) applied in December killed or severely stunted all plants but March treatment was less effective (Table 6).

TABLE 4

The effect of herbicides applied on 3 May to established E. ciliatum assessed on 5 July (Experiment 3)

Herbicide	Dose (kg/ha)	Vigour score (0-9)	Fresh weight shoots°	Herbicide	Dose (kg/ha)	Vigour Score (0-9)	Fresh weight shoots°
Clopyralid	0.2	3.8	65	2,4-D amine	2.0	0	0
Clopyralid W*	0.2	2.8	45	Diphenamid	4.5	6.8	105
Clopyralid O*	0.2	3.3	55	Paraquat	1.0	5.7	73
Chloroxuron	4.5	8.3	128	+ diquat			
Chloroxuron W*	4.5	5.2	44	Untreated		8.0	100
Chloroxuron O*	4.5	8.0	118				(606)+
Diuron	0.5	6.7	88				
Diuron	1.0	5.0	53	S.E. ±		0.68	14.8

* W, added wetter 0.5%; O, plus oil 5 l/ha; ° % untreated; + g/plot

TABLE 5

The effect of herbicide treatments on 3 and 18 May on established E. ciliatum assessed on 5 July (Experiment 4)

Herbicide	Dose (kg/ha)	Appl. date	Vigour score (0-9)	Fresh wt. shoots (% untreated)
Clopyralid	0.1	3 May	8.5	185
Clopyralid	0.2	3 May	4.0	22
Clopyralid +	0.1	3 May	3.5	37
clopyralid	0.1	18 May		
Clopyralid	0.2	18 May	4.0	36
Chloroxuron	2.25	3 May	8.0	137
Chloroxuron	4.5	3 May	6.5	138
Chloroxuron +	2.25	3 May	5.5	65
chloroxuron	2.25	18 May		
Chloroxuron	4.5	18 May	5.5	74
Clopyralid +	0.1)	18 May	6.5	82
chloroxuron	2.25)			
Chloroxuron +	2.25	3 May	5.0	38
clopyralid	0.1	18 May		
Untreated			7.2	100 +
S.E. ±			0.99	24.9

+ actual value 425 g/plot

TABLE 6

The effect of herbicides applied in winter and spring on established E. ciliatum assessed ib 18 June (Experiment 5)

Herbicide	Appl. date 18 December Dose (kg/ha)	Vigour (0-9)	Shoot height % untreated	Shoot fresh wt. % untreated	27 March Vigour (0-9)	Shoot height % untreated	Shoot fresh wt. % untreated
Diphenamid	2	5.0	75	56	-	-	-
	4	5.1	70	64	4.8	60	63
	8	2.6	28	12	1.9	19	4
Napropamide	2	6.0	78	66	-	-	-
	4	7.6	85	107	6.4	84	60
	8	5.5	77	68	5.4	73	60
Norflurazon	2	4.7	72	56	-	-	-
	4	0.5	30	8	5.0	67	45
	8	0	0	0	0.3	9	1
Oxadiazon	2.0	-	-	-	0.8	14	1
	4.0	-	-	-	0	0	0
Oxyfluorfen	0.5	5.7	79	60	-	-	-
	1.0	3.6	74	48	0.3	10	1
	2.0	1.0	23	4	0.6	16	2
Oxyfluorfen	0.5	3.2	62	30	-	-	-
(+ paraquat/	1.0	1.0	37	9	0	0	0
diquat)*	2.0	1.3	16	3	0	0	0
Paraquat	0.55	5.1	63	38	-	-	-
+ diquat	1.1	5.6	81	59	7.4	90	71
	2.2	3.5	68	24	6.1	74	59
Clopyralid	0.1	3.3	42	39	-	-	-
	0.2	2.1	21	8	0.3	6	1
	0.4	3.5	32	25	0.3	3	1
		Applied 17 April			Applied 16 May		
	0.2	2.1	36	66	2.7	47	60
	0.4	1.6	37	51	2.7	93	29
Untreated		8.2	100 (74cm)	(777)+	8.2	100 (74cm)	100 (777)+
SE ±		0.83	13.4	15.0	0.83	13.4	15.0

* doses of paraquat + diquat in mixture with oxyfluorfen corresponded to those applied alone. + g/plot

Oxyfluorfen applied in winter severely stunted plants but regrowth was vigorous except with 2 kg/ha. March treatment was more effective and the mixture with paraquat + diquat was even more toxic. Oxadiazon (2 kg/ha) applied in March also gave virtually complete kill. Paraquat + diquat at all rates applied in December killed much leaf growth and reduced subsequent growth but plants flowered profusely; March treatment was much less effective. Amitrole (4.4 kg/ha) at both dates gave virtually complete kill; glyphosate at all rates was ineffective in winter but 1.6 kg/ha in April gave severe long-term stunting of growth (data not shown). Clopyralid (0.2 kg/ha) in December, April and May resulted in long-term stunting of growth but surviving plants produced some flowers. March treatment gave virtually complete kill.

Experiment 6

Clopyralid (0.2 kg/ha) applied to vigorously-growing plants in April or May severely stunted growth although plant numbers were not reduced and some plants still produced a few flowers. The earlier application was somewhat more effective (Table 7). Split application of the April treatment separated by 5 days, did not improve control. Addition of phenmedipham (0.5 kg/ha) to clopyralid applied on 19 April did not improve toxicity but a split dose of the mixture gave greatly improved effects reducing plant numbers by 70% and severely stunting the remainder. Chloroxuron (4.5 kg/ha) only led to slight growth reduction. Addition of wetter (0.5%) to the April application did not improve effect but there was better effect from a split application of chloroxuron + wetter; most plants were killed or severely stunted. 2,4-D amine (2.0 kg/ha) killed all plants. Paraquat + diquat (1.1 kg/ha) caused severe leaf necrosis but plants largely recovered.

TABLE 7

The effect of herbicides applied in spring to a natural population of E. ciliatum (Experiment 6)

Herbicide	Dose (kg/ha)	Appln. date	Vigour (0-9) 20 May	Vigour (0-9) 18 June	Height tallest (% untreated, 18 June)	No. plants (% untreated, 18 June)	Fresh wt shoots (% untreated, 18 June)
Clopyralid	0.2	19 Apr	3.0	2.7	29	73	42
Clopyralid	0.2	16 May	5.0	2.3	53	100	51
Clopyralid*	0.1 0.1	19 Apr 24 Apr	3.0	1.7	23	98	43
Clopyralid + phenmedipham	0.2 0.5	19 Apr	3.0	2.3	35	68	33
Clopyralid +* phenmedipham	0.1/0.5 0.1/0.5	19 Apr 24 Apr	1.7	1.7	26	29	8
Chloroxuron	4.5	19 Apr	5.3	6.0	77	71	53
Chloroxuron + wetter	4.5 0.5%	19 Apr	3.7	6.0	73	35	45
Chloroxuron + wetter	2.25) 0.5%	19 Apr 24 Apr	1.7	2.0	24	6	5
2,4-D amine	2.0	19 Apr	1.0	0	0	0	0
Paraquat + diquat	1.1	19 Apr	5.3	6.0	77	85	56
Untreated			8.7	8.2	100	100	100
SE±			0.31	0.45	8.4	17.7	7.4

* repeated dose

DISCUSSION

Experiments on E. ciliatum occurring in fruit plantations in autumn were made less satisfactory because of the natural mortality of plants during the winter. This affected the experiment at Tiptree and more particularly at two other sites which had to be abandoned. This mortality did not occur where the weed was transplanted into plots in October.

Previous pot experiments have shown that there is a big difference in the response of E. ciliatum to the foliar and soil-acting herbicides used in fruit crops (Bailey and Hoogland, 1984). These results have been largely confirmed in the field experiments described in this paper. Diuron, diphenamid, napropamide and propyzamide all gave good pre-emergence control of E. ciliatum when applied in winter but only diuron showed significant post-emergence activity when applied to established plants. Winter applications of diphenamid (4.5 kg/ha) and to a lesser extent napropamide (4.5 kg/ha) reduced growth of established E. ciliatum but control was inadequate in that the plants recovered to flower profusely.

Safe and effective treatments that could be used in strawberry were therefore needed. Chloroxuron and clopyralid are both recommended on strawberries in the UK so the effect of spray timing and additives were investigated in greater depth. Clopyralid (0.2 kg/ha) gave the most effective control of established E. ciliatum if applied when growth was recommencing in early spring. Plants were severely stunted and largely prevented from flowering. Treatment in winter and later in spring was somewhat less effective particularly in preventing flowering of surviving plants. Addition of wetters, split application and mixture with phenmedipham failed to improve control significantly but a split dose of clopyralid/phenmedipham mixture with 5 days between treatment was very effective in 1985. Addition of extra wetter to chloroxuron (4.5 kg/ha) gave a marked improvement in effect in 1984 but less in 1985; however a split dose of chloroxuron + wetter was extremely effective in killing the weed in 1985. These results suggest there may be ways of using herbicides recommended in strawberries in spring to obtain control of established E. ciliatum.

For fruit crops where directed applications of herbicides can be made, a number of other herbicides gave effective control of the emerged weed, in particular amitrole, 2,4-D amine, oxyfluorfen + paraquat/diquat, oxadiazon and norflurazon. Paraquat + diquat and glyphosate were generally ineffective in preventing regrowth and flowering.

This work has therefore confirmed the effectiveness for pre- and post-emergence control of E. ciliatum of a number of herbicides recommended in fruit crops in the UK. Further work is needed to confirm the usefulness and safety of split application of clopyralid + phenmedipham and chloroxuron + wetter for control of established E. ciliatum in strawberries.

ACKNOWLEDGEMENTS

Thanks are due to Messrs J. Atwood and D.J. Johnston of ADAS for assistance with experimental work at Tiptree and Norwich and to staff of the former Weed Research Organization at Begbroke Hill for help with experiments there. The help of chemical manufacturers in the supply of the herbicides is gratefully acknowledged.

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EVALUATION OF ORYZALIN AND MOGETON FOR WEED CONTROL IN FIELD AND CONTAINER GROWN HARDY NURSERY STOCK

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ABSTRACT

Trials on newly planted field and container-grown hardy nursery stock have shown that oryzalin provides excellent broad spectrum weed control, including the most important species on containers, i.e. Cardamine hirsuta, Epilobium spp, Marchantia polymorpha (Liverwort), Oxalis corniculata, Poa annua, Senecio vulgaris and Sonchus oleraceus. Oryzalin did not adversely effect the crop vigour of approximately 500 woody and 80 herbaceous ornamental genera/cultivars treated. Slight phytotoxicity and/or vigour reduction was seen on 9 woody and 6 herbaceous cultivars. Results also showed that mogeton provides a very high level of control of both Marchantia polymorpha and Funaria hygrometrica (Moss) on containers. It did not effect crop vigour or quality of approximately 400 woody and herbaceous genera/cultivars treated and was equally safe and effective on crops grown under protection.

The results show that oryzalin or a tank mixture of oryzalin and mogeton will provide more effective and safer weed control on a wide range of hardy nursery stock than current commercial herbicides.

INTRODUCTION

The production of hardy nursery stock, especially in containers (Anon 1985), for amenity and home garden planting is one of the few growth areas in UK horticulture. However, one of the major limitations to economic and volume production is the high cost and availability of labour for hand weeding (Davison and Roberts 1976).

The search for effective and safer herbicides has been increased in recent years, e.g. the development and 'Approval' of chlorthal-dimethyl, propachlor and diphenamid, but the wide range of species grown and different methods of crop husbandry employed in the production of hardy ornamentals makes these objectives difficult to achieve. A particular problem in containers which are irrigated frequently is the weed spectrum that usually occurs, the most troublesome being Cardamine hirsuta, Epilobium spp., Marchantia polymorpha, Poa annua and Senecio vulgaris (Carter 1978).

Data from the USA (Anon 1983)had indicated that oryzalin, a residual herbicide from Eli Lilly & Co., might provide superior weed control with improved crop tolerance compared to existing products. Trials were laid down in 1983, 1984 and 1985 on newly planted container and field-grown trees, shrubs and herbaceous ornamentals.

In addition to annual grasses and broad-leaved weeds, mosses and liverworts are a serious problem on containers, reducing plant vigour and the marketability of the final product. Mogeton, (proposed common name for 2-amino-3-chloro-1,4-naphthoquinone) an algicide from Agro-Kanesho, was included in the 1984 and 1985 trials on containers for evaluation.

MATERIALS AND METHODS

A total of 12 trials on newly planted field grown stock were conducted in the period 1983-85. Details of trials location, soil and crop type, dates of planting, herbicide application and assessments are shown in Table 1 below.

TABLE 1
Details of field trials 1983-85

Trial No	Location	Soil	Crop	Planted	Dates Applied	Assessed
1/83	Sandwich, Kent	FSL	Trees/Shrubs	19/5	24/5	21/7
2/83	Bressingham, Suffolk	CL	Herbaceous	9/6	15/6	18/8
1/84	Fordham, Suffolk	FSL	Trees	1-18/4	19/4	18/6, 13/8
2/84	Chobham, Surrey	VFSL	Trees/Shrubs	1-17/4	18/4	23/5, 13/6
3/84	Bressingham, Suffolk	SL	Herbaceous	16/5	30/5	23/7
1/85	Pulborough, Sussex	FSL	Trees/Shrubs	1-15/5	16/5	17/6
2/85	Liss, Hants	LS	Trees/Shrubs	1-28/5	29/5	13/8
3/85	Bressingham, Suffolk	CL	Herbaceous	April	4/5	18/7
4/85	Abingdon, Oxon	SL	Trees	1-16/4	17/4	24/5
5/85	Bransford, Worc	L	Trees/Shrubs	1-13/6	14/6	12/7
6/85	Hereford	L	Trees	April	15/5	4/7
7/85	Hereford	L	Herbaceous	April	15/5	4/7

16 trials on newly planted containers were conducted in 1984 and 1985. Details of location and type of compost used are shown in Table 2 below.

TABLE 2
Details of container trials 1984-85

TRIAL NO	Location	Compost
4/84	Pulborough, Sussex	Peat
5/84	Chobham, Surrey	Peat, 10% loam
6/84	Woodbridge, Suffolk	Peat
7/84	Bressingham, Suffolk	Fisons potting
8/84	Fordham, Suffolk	Peat/bark
8/85	Chobham, Surrey	Peat
9/85	Pulborough, Sussex	Peat
10/85	Warburton, Sussex	Peat, 10% grit
11/85	Romsey, Hants	Peat
12/85	Canterbury, Kent	Peat, 20% grit
13/85	Bressingham, Suffolk	Fisons potting
14/85	Fordham, Suffolk	Peat/bark
15/85	Methwold Hythe, Norfolk	Peat/bark
16/85	St. Albans, Herts	Peat
17/85	Woburn Sands, Bucks	Peat
18/85	Bransford, Worcs	Peat

Trials were of single plot design, with each plot containing a range of ornamental species. Treatments were applied in 1983 and 1984 using either an 'AZO' propane gas sprayer regulated at 200 kPa or a CP3 knapsack regulated at 100 kPa. Both sprayers were fitted with a two metre boom with cone nozzles. Water volume was 267-333 litre/ha on field-grown stock and 2000 litre/ha on containers. The spray deposit was not washed off the crop foliage after application. The oxadiazon granules were applied with a 'Moderne' granule applicator.

In 1985 treatments were applied using the commercial spray equipment used on the nurseries concerned. This ranged from knapsack sprayers to tractor mounted booms. Water volumes ranged from 270 to 500 litre/ha on field crops and 2000 to 2500 litre/ha on containers. Herbicide deposit on crop foliage was not washed off after application.

Treatments applied to field crops are shown in Table 3, and to containers in Table 4 below.

TABLE 3

Field Treatments

	Treatment	Rate: kg ai/ha	Trials
A	Untreated control		All
B	Oryzalin (1)	2.16	All
C	Oryzalin	2.84	1985 only
D	Oryzalin	3.24	1984 only
E	Oryzalin	4.32	1983 & 1984
F	Chlorthal-dimethyl + propachlor	6.75 + 4.32	1983
G	Chlorthal-dimethyl + diphenamid	4.5 + 3.0	1984
H	Commercial Standards (2)		1985

Notes:

(1) Oryzalin was tested as a 75% ai wettable powder ('Surflan 75W') in 1983 and as a 480 g/litre aqueous suspension in 1984 and 1985 ('Surflan').

(2) Commercial Standards included simazine @ 2.2 kg; simazine + propyzamide @ 0.5 + 0.5 kg; diphenamid @ 3.7 and 6.7 kg and diphenamid + chlorthal-dimethyl @ 6.0 + 7.5 kg ai/ha.

TABLE 4

Container Treatments

	Treatment	Rate: kg ai/ha	Spray Interval in Weeks	Trials
A	Untreated control	-	-	All
B	Oryzalin (1)	2.16	9	1984
D	Oryzalin	3.24/3.36(2)	9	1984/85
E	Oryzalin	4.32	9	1984
F	Oryzalin + mogeton (3)	3.24/3.36 + 3.5	9	1984/85
G	Diphenamid + mogeton	3.75 + 3.5	6	1984/85
H	Oxadiazon 2% granules	4.0	12	1985
I	Commercial Standards (4)		6-12	1985

Notes:

(1) See Note 1, Table 3 above.

(2) Treatment D was increased from 3.24 kg ai/ha oryzalin in 1984 to 3.36 kg ai/ha in 1985.

(3) In 1984 mogeton was tested as a 50% ai wettable powder and in 1985 as both 50% and 25% ai wettable powders.

(4) Commercial Standards included diphenamid @ 3.5 and 4.5 kg; diphenamid + chlorothalonil @ 4.5 + 7.5 kg; oxadiazon @ 4.0 kg; chloroxuron @ 2.2 kg ai/ha and quinonamid @ 40 kg product.

Weed control was assessed in 1983 and 1985 as percentage weed cover and is presented as % weed control. The weed species present were recorded. In 1984 weeds were counted, by species, on each container or using a ¼ m^2 quadrat on field crops. Moss and Liverwort was assessed as % cover on containers and sandbeds and is also presented as % control.

Crop tolerance was assessed for each ornamental species using a 0-10 scale, where 10 = full vigour and 0 = plant death.

RESULTS

a) Weed Control on Field Grown Crops

Control of weed species and overall weed control on field grown crops is presented in Tables 5 and 6. Oryzalin at 2.16 to 3.24 kg ai/ha provided superior overall weed control compared to the standard treatments. Oryzalin gave better control of *Senecio vulgaris*, *Viola arvensis* and *Cirsium arvense* than the standard in 1984, and of *Capsella bursa-pastoris*, *Chenopodium album*, *Solanum nigrum* and *Matricaria perforata* in 1985.

TABLE 5
Field-grown crops
% Control of weed species, 8 weeks after application (1984 trials)

Weed Species	No of Trials	Untreated (No/m^2)	Chlorthal+ diphenamid	Oryzalin 2.16	Oryzalin 3.24	Oryzalin 4.32[1]
Senecio vulgaris	3	(12.2)	66	76	76	84
Stellaria media	3	(7.6)	100	94	97	100
Veronica arvensis	3	(6.1)	100	93	100	100
Polygonum aviculare	3	(3.3)	96	84	96	100
Myosotis arvensis	3	(1.2)	100	100	100	100
Viola arvensis	2	(33.3)	0	68	64	46
Chenopodium album	2	(14.6)	88	89	78	80
Cirsium arvense	2	(1.7)	79	100	100	100
Anagallis arvensis	2	(0.7)	100	100	100	50
Urtica urens	1	(8.0)	100	95	95	0
Bilderdykia convolvulus	1	(4.4)	64	27	64	36

Notes:
(1) Poor control of Viola, Anagallis, Urtica and B. convolvulus by oryzalin at 4.32 kg/ha was due to very variable weed infestation at one site.
(2) All treatments also gave complete control of low levels of Capsella bursa-pastoris, Lamium purpureum, Matricaria perforata, Polygonum persicaria and Trifolium repens.

TABLE 6
Field-grown crops
% Overall weed control 7-11 weeks after application

Treatment	1983[1] (2 trials)	1984 (4 trials)	1985[3] (5 trials)
Standard	79	58	86
Oryzalin @ 2.16	85	80	94
Oryzalin @ 2.84			93
Oryzalin @ 3.24		79 [2]	-
Oryzalin @ 4.32	90	66 [2]	-

Notes:
(1) Weeds controlled in 1983 trials were: Anagallis arvensis, Poa annua, Polygonum aviculare, B. convolvulus, P. persicaria, Senecio vulgaris, Stellaria media, Matricaria perforata and Veronica arvensis.
(2) See note 1 under Table 5.
(3) The predominant weeds controlled in 1985 were: Matricaria perforata, Solanum nigrum, Stellaria media, Capsella bursa-pastoris, Sonchus oleraceus, Polygonum aviculare, Poa annua, Senecio vulgaris and Chenopodium album. Oryzalin also controlled low levels of Galium aparine, Kickxia spuria and Chamomilla suaveolens.

b) Weed Control on Containers

Control of weed species and overall weed control on container-grown crops is presented in Tables 7 and 8. Oryzalin at 2.16 kg gave superior weed control compared to diphenamid but was inferior to oxadiazon granules. However, oryzalin at 3.24 and 3.36 kg was superior to all the commercial standard treatments. The level of weed control was not improved when the rate of oryzalin was increased to 4.32 kg ai/ha.

TABLE 7
Container-grown crops
% Control of weed species, 3 weeks after final application (1984 trials)

Weed Species	No of Trials	Untreated (No/m^2)	Oxadi-azon	Diphen + mogeton	Oryzalin 2.16	Oryzalin 3.24	Oryzalin 4.32
Cardamine hirsuta	5	(28.4)	88	33	54	88	88
Epilobium spp	5	(21.8)	63	52	67	93	67
Senecio vulgaris	4	(1.6)	92	17	18	67	60
Poa annua	4	(0.4)	40	100	100	60	100
Sonchus oleraceus	3	(2.4)	87	75	97	100	100
Papaver rhoeas	1	(1.3)	100	84	67	92	-
Cirsium arvense	1	(3.4)	2	100	100	83	100
Oxalis corniculata	1	(1.0)	78	51	100	100	96
Trifolium repens	1	(0.4)	0	60	40	40	100

Note: All treatments also gave complete control of low levels of *Festuca ovina*, *Holcus lanatus*, *Juncus conglomeratus* and *Rumex acetosella*.

TABLE 8
Container-grown crops
% overall weed control

Treatment	1984 (5 trials)	1985 (8 trials)
Oxadiazon	77	-
Diphenamid + mogeton	53	-
Oryzalin @ 2.16	63	-
Oryzalin @ 3.24/3.36	87	89
Oryzalin @ 4.32	86	-
Commercial Standards	-	78

c) Control of Moss and Liverwort on Containers

The results presented in Table 9 show that in both years of trials a tank mixture of oryzalin at 3.24 or 3.36 kg plus mogeton at 3.5 kg provided almost total control of Moss and Liverwort. Mogeton in mixture with diphenamid, which has little or no algicidal activity, gave complete control of Liverwort and 72% control of Moss. Oryzalin alone gave rather similar results of 99% and 63% control respectively. All these treatments were superior to the standard, oxadiazon.

TABLE 9

% Control of Moss (Funaria hygrometrica) and Liverwort (Marchantia polymorpha)

Treatment	1984 (4 trials) Moss	1984 (4 trials) Liverwort	1985 (8 trials) Moss	1985 (8 trials) Liverwort
Oxadiazon	37	76	-	-
Diphenamid + mogeton	72	100	-	-
Oryzalin @ 3.24/3.36	63	99	-	-
Oryzalin + mogeton	97	100	98	99

d) Crop Tolerance

Oryzalin has been tested on an extensive range of hardy ornamentals, too many to list in this paper. A summary of genera/cultivars tested is shown below:-

	Field Grown	Container Grown
Trees & Shrubs	65 cv's (48 genera)	450 cv's (118 genera)
Herbaceous Plants	58 cv's (38 genera)	23 cv's (23 genera)

There was no damage or vigour reduction on the field-grown trees and shrubs, except slight leaf scorch on Acer, Aesculus and Sorbus which were in young leaf at the time of treatment. Subsequent growth was un-affected. Of the field-grown herbaceous plants only Campanula, Chrysanthemum, Doronicum, Geum and Helenium were damaged by oryzalin, but these were also damaged by the commercial standard.

Of the many container-grown trees and shrubs tested, only Berberis, Cornus, Cotoneaster, Hypericum, Lavandula, Ligustrum, Lonicera, Physocarpus and Sambucus showed symptoms of slight leaf damage or reduction in vigour, but this did not effect final plant quality. Chrysanthemum and Doronicum were also damaged when container-grown, as was Polygonum.

Mogeton was also tested on a wide range of container-grown trees, shrubs and herbaceous plants, both outdoor and under protection. There was no damage or vigour reduction on any cultivar treated.

DISCUSSION

Results of trials over three years have shown that oryzalin at 2.16 or 2.84 kg ai/ha provides excellent weed control (80-94%) on field-grown nursery stock. The spectrum of control includes all the important field species. It is likely that the higher rate of 2.84 kg will only be needed on the heavier soils or when extended weed control is required e.g. early season planting or in the second year after planting.

Results also show that oryzalin at 3.26 kg ai/ha applied at 9 week intervals gives a very high level (87-89%) of weed control on containers, including the most troublesome species i.e. Cardamine hirsuta, Epilobium spp and Marchantia polymorpha. However, due to the high value of nursery stock, crop safety is of even greater importance than herbicidal efficacy. Oryzalin has shown excellent safety over the extensive range of ornamental species tested.

Mogeton has also shown exceptional crop safety when applied at 9 week intervals to containers both outdoors and under protection. 3.5 kg ai/ha has provided complete control of M. polymorpha and 72% control of Funaria hygrometrica. Results, not presented here, have shown that at 7.0 kg ai/ha, mogeton will eradicate established infestation of both M. polymorpha and F. hygrometrica.

Oryzalin or a tank mixture of oryzalin and mogeton gave more effective and safer weed control on a wide range of hardy nursery stock than current commercial herbicides.

ACKNOWLEDGEMENTS

The authors wish to thank the many Nurserymen and their staff who co-operated in the trials and their colleagues within ICI Midox who carried out the work reported in this paper.

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SESSION 9A

APPLICATION TECHNIQUES AND THE ENVIRONMENT

CHAIRMAN PROFESSOR W. FLETCHER

SESSION ORGANISER DR R. C. ROBINSON

INVITED PAPERS 9A-1 to 9A-6

REVIEW OF THE BCPC 'APPLICATION AND BIOLOGY' SYMPOSIUM

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INTRODUCTION

The British Crop Protection Council hold each year a number of symposia in addition to its major annual conference at Brighton. One regularly covered topic has been pesticide application and the sixth BCPC applications symposium, which is reviewed here, was held at the University of Reading in January 1985. Previous applications symposia have covered research work in pesticide application (London 1970), ULV methods (Cranfield 1974), granules (Nottingham 1976), Controlled Droplet Application (Reading 1978) and Spraying Systems for the 1980's (Egham 1980).

These symposia attract an international audience and possibly because of the small size of the application discipline within crop protection, a very complete and representative one. They also serve as a useful regular gathering of those interested in the subject, with perhaps as much information and experience being exchanged outside the sessions as during them. It has been the intention of most of these symposia to appeal to such a wide cross-section by providing a mix of scientific, technical and practical papers.

PLAN

The theme of the Application & Biology Symposium was to explore the various relationships between the influences of application systems and of biological characteristics on the activity and effectiveness of pesticides. This was known to be a difficult subject area especially when tackled on a broad front of interests and levels.

Application is clearly critical to the correct and safe performance of agrochemicals. No matter how good the product its potential will be severely reduced and the safety to the environment endangered if incorrectly used. Many proposals have been put forward in recent years to try to significantly improve the performance of existing methods. It is not always easy to acquire factual data to support claims of improvement. It has proved even more difficult to understand why existing hydraulic nozzle sprays can work at all, if so allegedly wasteful or why novel techniques with much logical promise of improvement do not always demonstrate such improvements in practice.

The programme followed a pattern moving from reviews of state of development of conventional systems, to presentation of new performance data on newer techniques. The session devoted to the influence of formulations and adjuvants proved, as expected, to be a great problem in getting papers on formulation design, particularly from industry. Two sessions covered the vital area of relationship between the influence of physical characteristics of nozzles, spray clouds, transport, canopies, etc and of biological characteristics of the target on the performance of pesticides. A lengthy general discussion was held at the end to give an opportunity for further discussion on areas of key interest.

An exhibition of technical data and equipment for the production, sampling, sizing of droplets, collection of meteorological data and topics of related interest to applications was held concurrently.

REVIEW OF PAPERS PRESENTED

Altogether 36 papers were presented from the platform or as posters and it is impossible to review each one individually. At the risk of omitting some authors' important results and arguments, I have based this review on the main topics covered, hoping that readers will refer to the symposium proceedings for the considerable amounts of data and conclusions contained in the papers.

Spray formation and movement

The major problems still facing application workers trying to define just what their spray clouds contain was reviewed by B. Young. He stressed the need to drop the element of competition between different laser systems used for droplet sizing and use them advisedly with better understanding. He suggested traversing the beams through multi-nozzle, overlapping sprays to simulate more closely real conditions. He considered drop velocity had an important influence on reflection and penetration of drops and had been underestimated.

H. Goelich discussed the influences on spray clouds, showing how penetration into and coverage of a canopy are affected by filtering out of larger drops and by evaporation. Coverage can be improved and drift reduced by the down-draught from air-foils on the boom.

Penetration, retention and deposit

Many of the results presented showed how difficult it is to directly compare work in different crops, with different techniques and approaches. N. Western found in cereals that hydraulic sprays with small drops were captured relatively well and that larger drops deposited poorly on base of young plants but penetrated well into taller crops. Rotary atomizers gave generally poor penetration and retention.

Other authors noted that retention could be influenced by drop size, volume rate, formulation and concentration, plant type, leaf area index and method of spray production.

B. Cooke pointed out that enhanced retention did not always give better biological results. J.H. Combellack suggested that variation in collection efficiency might explain in part differences in crop tolerances to certain herbicides.

Variation in deposit was clearly an important feature in much of the work presented. A number of papers showed rotary atomizers giving worse coefficients of variation of deposit than hydraulic nozzles. J. Bryant suggested that this could be due to difficulty in getting an even distribution from a multiple unit boom and the susceptibility of rotary atomizers to boom movement and spray displacement by wind. Deposit evenness was found to be influenced by pressure, boom height, nozzle orientation and formulation. P. Ayres concluded that even with considerable variation of deposit, uniform biological activity could still be obtained.

Dose and volume rate

W. Taylor, reviewing the use of rotary atomizers, stated that dose and timing of application affected biological performance far more than volume rate and drop size. Similarly, P. Ayres found that dose and canopy affected weed control more than volume rate and drop size, or even application method. P. Herrington found that control of mildew in apples was better at 500-800 l/ha than at 50 l/ha, even when using systemic fungicides. She considered that lower volume rates should not be used to reduce fungicide dosages.

Formulation

The influences of formulation, surfactants and other components of products, were discussed by several authors, their main problem seemed to be how to select them. It was noted that surfactants could reduce drop size, improve penetration of bark, enhance activity and reduce movement within the plant. J. Zabkiewicz used contact angles of droplets on target wax extracts to select suitable surfactants.

Comparative performance

Many comments on the influence of spray production on biological performance were concerned with comparison between hydraulic nozzle and rotary atomizer spraying equipment; most concluding that hydraulic nozzles were biologically more effective, although differences were small.

In very specific trials with herbicides at repeated low doses in sugar-beet, M. May found equivalent performance at volume rates of 80 l/ha and that neither nozzle size, forward speed nor method of application seemed to influence biological performance.

Electrostatic spraying

It was noted by G. Cayley that higher deposits could be achieved with a charged rotary atomizer but these did not always increase performance. Two reports of trials with charged hydraulic nozzle sprayers showed no significant advantage in performance over similar uncharged systems.

Non-spray applications

The symposium was dominated by spray application systems but a number of important points were raised by those reporting on other methods. D. Harris reviewed many of these pointing out their relevance in specific situations. He stressed that, perhaps in common with spray application systems, the advent of newer, more active products and more highly concentrated formulations required greater accuracy of use and care in handling. Accuracy of placement of granules was found by D. Smith to enable reduction of dose, especially in block or module systems. P. Baughan discussed special coatings for seeds which allowed higher and more accurate loadings than possible with a conventional seed-treatment system.

In quite a different area, the use of rope-wick applications with selective herbicide was found to be better within the canopy than with a non-selective product above it.

General points

There were many interesting and important points raised and discussed during the symposium. I. Rutherford and several other speakers pointed out that although the hydraulic nozzle sprayer is effective, versatile, efficient, fast and safe, there is a need for better training, maintenance, drift control, better codes of practice and guidance on nozzle selection.

Several speakers called for more care in collecting information on spray characteristics, partitioning and fate of the spray and on meteorology. Also for more understanding and information on the newer application techniques.

T. Mabbett called for a multi-disciplinary approach to application research and pointed out that timing of application must account for weather, crop growth and pest stage. There were also warnings against making generalisations, even with such apparently straightforward aspects such as boom height.

SYMPOSIUM DISCUSSION

Not surprisingly many of the points raised in the presented papers were also covered in the lengthy discussion period at the end of the symposium, led by I. Graham-Bryce.

Droplet size

C. Pay asked how optimum droplet size and droplet density on the target, so often quoted, were derived. Some ADAS results using rotary atomizers had indicated preferred sizes for certain situations. Practical physical dimensions of rotary atomizer equipment were found by E. Bals to determine sizes which could be produced.

I. Graham-Bryce noted that several cases had been presented for wide droplet spectra. There was general agreement for this, E. Hislop considering that mono-sized sprays needed the objective of using the absolute minimum spray volume rate. D. Bache felt that a reasonably wide spectrum was needed when we were so uncertain of the relationships between the spray, its transport and impaction on the target and the target itself. Considering closely controlled droplet sizes to form a spray would cause a problem, J. Spillman linked the argument against mono-size sprays to the large number of and our lack of knowledge of the targets. There was also concern that there was a conflict between small droplets needed for better retention and potential drift and also the danger of drift associated with low volume rates and higher forward speeds.

Mass balance

A number of contributors mentioned the need to determine the fate of all components of the spray and that this was missing from many papers. R. Courshee said that a surprising amount of spray could be found on the canopy, especially when properly applied. G. Cayley had found that 50% of chemical can get through to the soil with hydraulic nozzles in cereals at growth stages 30-32.

Coverages

In reply to a question about the relationships between coverage and biological efficacy, G. Matthews said that fundamental studies were necessary to understand the amount of cover needed. I. Graham-Bryce said that work at East Malling Research Station had shown coverage to be important in interpreting the relationship between droplet density and biological activity. Once a minimal cover has been achieved biological control was less dependant on coverage.

Formulation

D. Seaman asked if an ability to predict the selection of surfactants was any closer. D. Turner said that the surfactant must interact with application method, environment and biochemistry of the plant. Surfactants can be biologically active, can increase uptake or reduce movement within the plant. He felt we had to continue with an empirical approach and warned against closely correlating work with glasshouse plants to those in the field.

Controlled release

In a contribution on controlled release systems of pesticide application, C. Furmidge felt that these were coming back into perspective. Several control mechanisms were available - diffusion, leaching, erosion and breakdown, mechanical and physical placement, encapsulation. Problem areas are cost, timing, secondary pest control, mixtures, registration and technical competence of users. Despite these, it should be an exciting subject for specific situations.

SUMMING-UP OF SYMPOSIUM

In his summing up of the conference, I. Graham-Bryce pointed out that the challenge seems to be getting greater. Comparing DDT, dimethoate and deltamethrin, there was a 50 fold reduction in dose rate but a 1000 fold difference in intrinsic activity.

He considered there were two overriding objectives - to apply a just lethal dose to each damaging organism avoiding unintended recipients and to ensure ease of use and robustness of performance under varying conditions. These have to be achieved by specifying the pattern of concentration of active ingredient in time and space to give optimal performance and devising the method of achieving that specification.

New techniques were achieving some success but still had quite a way to go. We must avoid fruitless searches for a 'philosopher's stone' and avoid generalisations. Methods of application other than spraying and the influence of formulation need more emphasis.

We should move from physical post-event interpretations to a more analytical approach to define the specification we need to characterise target organisms and situations. There is a need for a more multi-disciplinary approach.

The key missing component in the relationship between application and biological performance is quantitative knowledge of the biological requirement.

CONCLUSIONS

The most notable conclusion is, as often expressed before, that we are still a long way from being able to adequately relate the variables affecting performance. Amongst the most notable conclusions of the Symposium were that dose and timing of application are more influential than spray characteristics, at least where complex targets are involved. Volume rate and transport to target seem to be more important than drop size. Clearly there was much unhappiness with very closely controlled droplet spectra, especially when the target was poorly defined. Many speakers were worried about poor deposit variability they encountered.

The newer techniques, particularly rotary atomizers and electrostatic spraying, do not seem to be improving performance as hoped. Their place however seems assured, particularly as one speaker mentioned if used as 'horses-for-courses'.

It was a shame that no papers on the influence of formulation design were presented, but those on adjuvants and surfactants showed that a great deal more work needs to be done to understand their actions so they can be predictively selected.

There were many calls for more research work into pesticide application. The calls for a multi-disciplinary approach were particularly important underlined by the wide-ranging nature of the various problem areas discussed. The prospect of legislative control in the UK must spur on such efforts and also the better and safer use of application equipment.

It was also a shame that other application methods such as seed treatments and coatings, granules, controlled release, etc. did not feature more prominently. Speakers on these topics held great promise for the future - perhaps the subject for another symposium?

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APPLICATION METHODS : THE INTENTIONS OF THE NEW LEGISLATION

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Paper available separately.

THE REGULATION OF AGRICULTURAL AVIATION IN THE UNITED KINGDOM

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SUMMARY

The involvement with agricultural aviation of any public agency will be concentrated on three main subjects. First, regulation of aerial application operations by supervision of the companies involved. Secondly, setting and ensuring the maintenance of standards for individual pilot competence. Thirdly, the supervision of aircraft certification and maintenance in this arduous environment. The last of these three is primarily the concern of the Authority's Airworthiness Division and will not be dwelt on in this paper.

OPERATIONAL CONTROL

Aerial application, whether of pesticides, herbicides, fertilizer or whatever, has become part of the modern agricultural system. In order that an aircraft may apply a substance from the air however it must fly at very low level. Both low flying and the dropping of articles from aircraft have long been restricted by the air legislation in the United Kingdom. The UK is a densely populated country and agricultural aviation operations may be expected to impinge on the general public to a greater extent than in more spacious countries. The public has a right to expect that any activities which could adversely affect it if not correctly performed, should be properly conducted and regulated. Agricultural aviation by its very nature, contains elements which tend to alarm the general public. The combination of low flying and application of substances which are often toxic will almost certainly be disturbing to the uninitiated observer. At the same time the value of aerial application to agriculture and thus to the community as a whole has to be recognised. Specifically the regulation of aerial application in the UK is exercised through the Air Navigation Order 1980 (S1 1980/1965) as amended. The two articles therein which have the most direct impact are Articles 39 and 40.

Article 39 has two sub sections. The first, Article 39(1) says, in effect, "articles shall not be dropped or permitted to drop from an aircraft in flight so as to endanger persons or property". There is never any concession from this requirement. The second sub-section Article 39(2) says, "nothing will be dropped from an aircraft flying over the United Kingdom except in certain laid down circumstances." The circumstances which come within the scope of this talk are:-

> the dropping of articles for the purposes of agriculture, horticulture or forestry under and in accordance with the terms of an aerial application certificate issued under Article 40.

These then are the two main pieces of legislative control but before going on to discuss in detail how these are applied I would mention two other parts of aviation legislation which apply to aerial applications. They are Article 42 of the Order which prohibits the carriage of dangerous goods in an aircraft and Rule 5(1)(e) of the Rules of the Air and Air Traffic Control Regulations 1981 (made under the powers of Article 61(1) of the ANO 1980) which prohibits flight closer than 500 ft to any person, vessel, vehicle or structure. Quite obviously these have an effect; in the case of the former in the carriage of chemicals and in the latter in the ultra low flying necessary in aerial application.

In the case of Art 42 the Authority issues a permission which includes conditions, among which is a limit to what can be carried. In the case of the low flying restriction the Regulations contain a built-in exemption to the effect that the provision does not apply to flights in accordance with an Article 40 certificate.

By far the largest type of aerial application is that carried out under Art 40 certification. This is the dropping of articles for the purposes of agriculture, horticulture and forestry or for training for such dropping. Part (2) of the Article states that the Authority will grant to a person the necessary certificate if it is satisfied that that person is a fit person and is competent to secure the safe operation of the aircraft specified in the certificate. Part (2) goes on to specify certain matters which have to be taken into account before the Authority issues the certificate, ie

(a) the applicant's previous conduct and experience
(b) his equipment
(c) his organisation
(d) staffing
(e) other arrangements to secure a safe operation.

Part (3) of the Article requires every operator to make available to the Authority and to every member of his operating staff an aerial application manual containing instructions and information to enable the staff to perform their duties. The operator is required to make such amendments or additions as the Authority requires. This is the control mechanism for aerial application.

There is of course more to aerial application than spraying. There is nowadays quite a lot of fertiliser work and some seeding etc. However all the activities are covered by the aerial application certificate a condition of which is that every flight under this certificate will be in accordance with the relevant provisions of the certificate holder's aerial application manual. We in the Authority provide guidance which is contained in our publication CAP414 entitled "The Aerial Application Certificate" on the production of the operators manual, and in our vetting of the manual require certain matters to be covered. These include purely aviation matters such as fuel requirements, aircraft maintenance, aircraft performance, weather minima etc and also matters to do with the safety of persons and property on the ground. We also require operators to include in their manuals matters to be taken into account to minimise hazard, annoyance, distractions, deleterious effects by examining the target area and the area within three quarters nautical mile of its boundaries (eg Chapter 2 para 5.1.2 on reconnaissance). Other requirements to be covered in the operators manual are prior notification of operations (Chapter 2 para 5.1.10) as follows:-

(a) Office of chief constable

(b) As far as practicable occupants of buildings, owners or agents of livestock or susceptible crops on land with boundaries within 75 feet of the target area.

(c) Any hospital, school etc within 500 ft of any potential flight path.

(d) The Nature Conservancy Council if necessary.

(e) The reporting point of the local bee-keeper's spray warning scheme where appropriate.

A wide spectrum of requirements and information must be included in the operators manual. One of the most important matters concerns the minimum distances pilots can fly from occupied dwelling houses and other buildings (Chapter 2 para 5.2.3): eg a requirement that flight is not to be below 200 ft over occupied buildings: That there is to be a minimum horizontal distance of 200 ft from such buildings when flying below 200 ft; The need to avoid flying directly over, even at heights in excess of 200 ft, especially sensitive areas such as schools, hospitals and also to remain 200 ft horizontally from such sensitive areas. The minimum distance from congested areas when flying below 1500 ft to be at least 200 ft. Another important matter covered by the operators manual is the control of what can be applied. In this respect the Authority depends on advice via the Pesticides Safety Precautions Scheme of MAFF, who publish a list of chemicals which can be applied. This list, or those chemicals included in it, has to be put in the operator's manual, with instructions to the effect that chemicals not contained in the list cannot be applied from the air. We would not accept a manual without these and many other requirements.

The manual, as stated previously, is part of the control mechanism in that it spells out how operations should be carried out. Flight in breach of the manual requirements could be in breach of Art 40(1) and could lead to enforcement action against the pilot and/or operator concerned. It is appropriate to mention here that the Health and Safety Executive, the police and CAA have set up a working system for the handling of complaints. A high percentage of complaints are made to local police who have instructions to pass them immediately to the local office of the HSE. They in turn notify the Authority where there is any question of mis-application of spray or drift on to non-target areas. HSE investigate and let the authority have a copy of their report. Where the complaint is a purely aviation matter further investigation is carried out by the Authority. During the years 1980 - 1983 the number of complaints received by the Authority averaged about 125 a year. The number received in 1984 showed a marked increase to 210. So far in 1985 the Authority have received 125 complaints. The decreased number received in 1985 may, in part, be a result of the action taken by the Authority at the end of 1984 in tightening up the requirements for giving prior notification and increasing the distances that may be flown from occupied dwelling houses and other buildings.

I would like to turn now to the way the Authority certificates operators. A new operator would be required to:-

(a) make available to the authority his Aerial Application manual which would be assessed against requirements and guidance of CAP414.

(b) submit details of his management set up, accommodation, base etc to us.

(c) submit to a base inspection.

The control of his operation after the issue of the certificate is then an ongoing matter with field inspections etc. These field inspections are sometimes carried out in conjunction with inspectors of the Health and Safety Executive, who have a responsibility concerning the safety at work of the operators' employees and others under the Health and Safety Legislation.

In round terms this is the system of regulation. At the moment there are 34 certificated operators using some 75 aircraft.

PILOT LICENSING

Pilots engaging in aerial application are required to hold the appropriate licence. In the case of a commercial operator this would require the pilot to hold a professional licence. Furthermore, an operator's Chief Pilot is required to have a minimum experience of 500 flight hours in command on aerial application work extending over two seasons preferably in the UK.

Other agricultural aviation pilots must have completed a training course, normally given by the operator, to a syllabus that has to meet the requirements of the CAP414 and which is then submitted to the Authority as a training manual. It should be said that consideration has been given in the past to introducing an agricultural and chemical rating to the pilot's licence, but for various reasons has been discarded in favour of the existing system.

CONCLUSION

The foregoing describes how the agricultural aviation industry is regulated by the Authority in the UK. There is an ongoing monitoring of these requirements in order to ensure they are suitable and matched to meet the Authority's safety standards in the changing world in which we live. It is, I think, common knowledge that 1984 produced an unprecedented volume of complaints and criticism of the industry as a whole, too often brought about by carelessness and lack of concern for the sensitivities of the public. Since the majority of the complaints were allegations of chemical drifting outside the target area it is the personal opinion of the author that the research efforts of the whole industry should be positively directed towards the containment of the treatment to the target thus helping towards a reduction in the number of complaints made by the general public which must, surely assist in allaying their fear and concern about the use of chemicals in agriculture: Thereby, hopefully leading to a significant improvement to the image and acceptability of the industry as a whole.

OPERATOR TRAINING: A KEY ELEMENT IN SUCCESSFUL APPLICATION

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ABSTRACT

If modern crop protection chemicals are to be applied safely and effectively operators must be trained. Whilst it is difficult to determine the current standard of operator competence on British farms it is possible to establish a basic level of skill necessary to ensure efficient maintenance and operation of application equipment, and meet employers' and employees' responsibilities under current health and safety legislation. The Agricultural Training Board, the main provider of training for adult workers within the industry, has established operator learning objectives at a basic and advanced level and is developing training courses which enable these objectives to be achieved.
The success of training is often dependent on the delivery systems and whilst new methods of providing training are available it is apparent that Instructor based systems will be the main method of delivery in the foreseeable future.

INTRODUCTION

The expanding use of chemicals to control weeds, pests and diseases, and regulate crop growth has contributed to a steady increase in crop output.

This greater than ever use of crop protection chemicals has resulted in the field crop sprayer becoming the key machine on many farms. Indeed a sprayer may pass through a winter cereal crop as many as six times during a season, applying a variety of sophisticated chemicals at precise application rates.

To get the best out of a sprayer and the expensive chemical it is applying, it is even more essential that the sprayer is prepared, maintained calibrated and operated effectively. It is therefore important that operators of application equipment possess the basic skills which enable them to prepare a sprayer for work and apply safely and efficiently a wide range of crop protection chemicals.

Recently there has been much comment on the quality of sprayer operators within the U.K. and many people, principally with interests in chemical or machinery manufacturing, have expressed the view that current crop sprayer operator training is inadequate, indeed some have called for the compulsory training and licensing of all operators.

COMPETENCE OF CURRENT OPERATORS

It is extremely difficult to assess the standard of current operator performance throughout the U.K. However a number of indicators are available and these are considered under the headings : Operator Safety, Drift and Environmental Factors, and Efficacy.

Operator Safety

The main source of information regarding operator safety is the Health and Safety Executive accident statistics which record fatal and non-fatal accidents occurring as a result of chemical use at work. These statistics indicate that pesticides are not a significant operator safety problem when compared with other farming operations. However it could be argued that any poisoning incident is unacceptable. The Health and Safety Executive is currently conducting an investigation into the need for further legislation and advice regarding the safe use of chemicals on the farm.

Drift and Environmental Factors

Much emphasis has been placed recently on the dangers of spray drift and the effect on other crops and wild life. Great importance has been attached by Government and other agencies to the need to make operators aware of the dangers of drift and factors which lead to its occurrence. There appears to be little evidence currently available on the incidence of crop damage and the effect on wild life as a result of drift levels caused by crop sprayer operation. However, the Seventh Report of the Royal Commission on Environmental Pollution (CMND 7644) indicated that there was a potential problem as a result of the use of pesticides and that more emphasis should be placed on the training of operators. The recent Government response to this report (Department of the Environment 1983) recommended a national framework for co-ordinating training provision and the monitoring of proficiency standards in pesticide application. It would seem that the recently enacted Food & Environmental legislation could provide a useful vehicle for any government initiative in this direction.

Efficacy

There is little current research evidence available on the efficacy of spray application on the farm and such evidence that is available is inconclusive. The ADAS Mechanisation Liaison Unit crop sprayer investigation in 1976 indicated that the level of accuracy arising out of chemical application on farms was inadequate, but this survey was carried out on a very small sample of crop sprayer users. A recent NFU internal survey of members indicated that farmers in general are satisfied that, having regard to farm circumstances, the maximum possible safety and efficiency is achieved in spray applications. However, it must be said that this survey was somewhat subjective and carried out on only a very small sample of farmers.

In view of the lack of objective information on operator performance it is difficult to determine the total requirement for the training of people currently applying crop protection chemicals. It is however clear that operators do require training if they:-

a) Do not possess the basic skills which enable them to apply a chemical safely and effectively with minimum risk to the environment, or

b) Are carrying out the operation for the first time, or

c) Are required to operate a new type, make or model of machine, or

d) Require new or more advanced skills.

A LEGAL REQUIREMENT

Current Health and Safety legislation recognises this need for training in that it is a specific requirement of the Poisonous substances in Agriculture Regulations 1984 that no person shall cause or permit an employee to work on a scheduled operation unless the employee has been thoroughly trained in the precautions to be observed and is under adequate supervision. The self-employed are also prohibited by these regulations from work on scheduled operations unless having a thorough knowledge of the precautions to be observed.

In addition under section 2 of the Health and Safety at Work etc, Act 1974 an obligation is placed on every employer to ensure, so far as is reasonably practicable, the health, safety and welfare of his employees. There are several areas into which this obligation extends and the Act includes in particular "the provision of such information, instruction, training and supervision as is necessary ....."

Failure to comply with the Act or Regulations may lead to prosecution and a maximum fine of £2000. There is no limit to the fine if conviction under the Act is an indictment.

The Health and Safety Executive are soon to offer guidelines on what they consider to be adequate training and the basic Agricultural Training Board (ATB) crop spraying courses are designed to meet these criteria.

It is argued by representatives of the employers within the agricultural industry that the above legislation, if enforced, is sufficient to ensure a basic level of operator competence without the need for further statutory measures or licensing schemes.

CURRENT TRAINING PROVISION

It is extremely difficult to determine the total amount of crop sprayer operator training available to the industry as many agents, agricultural colleges, farmers, local authorities, chemical manufacturers and Industrial Training Boards are involved.

There is little doubt that the Agricultural Training Board is the main provider of post experience crop sprayer training to commercial agriculture and horticulture. During 1982/83 the Board carried out 329 crop sprayer courses involving some 2138 people. As this figure does not represent the total number of people trained in pesticide application that year and takes no account of the number of persons requiring training it is difficult to establish if current provision meets the needs or indeed the demands of the industry. The Agricultural Training Board certainly has the instructor capacity to meet a higher volume of demand, although an increase in such training would require further financial resources from the industry.

THE OBJECTIVES OF TRAINING

The aim of training should be to provide trainees with the skills necessary to carry out a particular activity and the assessment of the outcome of the learning process should be the ability of the learner to successfully undertake these skills. Such performance following training is often described by theorists as "terminal behaviour" and the desired outcome in terms of "learning objectives".

The ATB has recently undertaken a major development programme to provide a series of short courses to meet the current and future needs of crop sprayer operator training. These courses are also being tailored to fit the requirements of agricultural contractors and the National Association of Agricultural Contractors is working with the ATB to evolve a scheme for the training of their members.

This training is to be provided at two levels, Basic and Advanced, in order to meet the needs of all persons applying crop protection chemicals, and is described below in terms of learning objectives.

Basic Level

This will be the minimum standard expected of any operator and in addition to meeting the requirements of current Health and Safety legislation is in line with the criteria of the National Proficiency Test Council's crop sprayer proficiency test.

Following training participants will be able to :

(1) Identify those aspects of safety legislation which apply to the safe use of chemicals and, in particular, user responsibility under the Poisonous Substance in Agriculture Regulations.

(2) Use the information detailed on container labels, and from other sources, to determine the hazard of and precautions to be taken when applying a particular substance.

(3) Identify the correct protective clothing for use with a particular substance.

(4) Carry out the correct procedures for handling, mixing and storing chemicals and the disposal of empty chemical containers.

(5) Take necessary emergency action to decontaminate persons and obtain specialised assistance in the event of accidental poisoning.

(6) Prepare appropriate chemical applicator for work according to manufacturer's recommendation.

(7) Carry out daily and routine maintenance to appropriate chemical applicator as specified by the manufacturer.

(8) Adjust and calibrate appropriate chemical applicator to achieve a desired accurate application rate. (In accordance with the BCPC/ATB National Calibration procedure)

(9) Operate the appropriate chemical applicator ensuring correct application rate, overlap and distribution.

(10) Identify common faults and rectify these as they occur and be able to identify faults which require specialist attention.

(11) Carry out the correct procedure for cleaning clothing and application equipment which is contaminated with chemicals.

(12) Complete records necessary to meet user's obligations under Health and Safety legislation.

These training objectives apply to all parts of the country irrespective of the level and quantity of work and enable operators to apply a given volume of crop protection chemical safely whilst ensuring the desired degree of efficacy.

Advanced Level

This is aimed at the person who has reached the basic standard but needs a greater understanding of the factors affecting crop sprayer performance in terms of efficacy and efficiency. It takes into account the quality as well as the quantity of application and provides the skills necessary to get the best out of the sprayer and ancillary equipment. It is suggested that this is the level which should be reached by the operator on the larger arable farm and the agricultural contractor.

This training is provided in two parts :

(1) Advanced Application Techniques

Following training participants will be able to :

(a) Explain the importance of volume rate, drop size, mode of action, target and environment.

(b) Identify the appropriate drop size and spectrum for a particular target and environmental condition.

(c) Identify conditions which create a drift hazard.

(d) Identify nozzles and correctly select them for a particular application and product.

(e) Set an applicator to achieve accurate application of a particular spray quality.

(f) Carry out effective calibration.

(g) Minimise the effect of boom instability.

(h) Describe the benefits of other application techniques, in particular CDA and electrostatics.

(2) Better Spraying Techniques

Following training participants will be able to :

(a) Select a particular chemical formulation.

(b) State chemical mode of action and its effect on application.

(c) Safely mix compatible crop protection products.

(d) Select and use electronic and other aids to accuracy.

(e) Use AVR Systems to maintain accuracy.

(f) Carry out field planning and organisation to maximise efficiency.

One advantage in describing training in terms of learning objectives is that it defines precisely the skills required but does not dictate the way in which training should take place.

THE DELIVERY SYSTEMS

For training to reach the sprayer operator there must be a delivery system. There has been much discussion on training delivery arising out of the Manpower Services Commission's new training initiatives for Open Learning (1981) and adult training (1983). However the following appear to be the most likely to provide crop sprayer training in the future.

Instructor Based

This is the more conventional method of delivery where an instructor, with or without aids such as video, charts etc., instructs trainees face to face. The instructor, often a technically able person who has received training in instructional techniques, shows the trainee skills which must then be practised under supervision. Such training can take place off-the-job, where trainees attend a course. This may be held at their place of work but will be away from their normal work activities. Alternatively it might take place on-the-job, where training is provided at work by the farmer or supervisor who has been trained in instructional skills. The latter is particularly suited to large businesses or where there is a high turnover of casual labour such as mobile seed cleaning contractors.

Open Learning

Open Learning is defined by MSC to be arrangements that enable people to learn at the time, place and pace which satisfies their circumstances and requirements. The emphasis is on opening up opportunities by overcoming barriers that result from geographic isolation, personal or work committment or conventional course structures which have often prevented people from gaining access to the training they need.

Although Open Learning is considered to be a new approach to training and education in agriculture the ATB's current delivery system could also be described as being Open in that it permits flexibility in terms of the time when training takes place, level of entry required, location of training and material learnt.

In practice the new open learning schemes available (Open University - Pest and Disease Courses) and those being developed (Welsh Agricultural College - Grassland Management; Lincolnshire Agricultural College - Arable Crop Management; A.T.B. - Mushroom Production) follows the distance learning approach where self learning material is mailed to participants, possibly supported by some form of tutorial arrangement. It is difficult to assess how successful such an initiative will be in agriculture as little market research has been carried out. There are many farmers and growers who could benefit from such training but it is still to be determined whether or not these persons are prepared to study self learning material following a hard day's work.

It is unlikely that any distant learning package for crop sprayer operators will be developed in the foreseeable future.

Information Technology

Video systems and micro computers offer the option for self learning, technical updating and refresher learning.

Video has already been used by chemical and machinery manufacturers to provide advice and training for crop sprayer operators and in one case a major farming journal has produced a video tape supported by advertisements and is available to users at minimal cost. It is difficult to determine the take up of these tapes, but they do provide an excellent means of refresher training whereby the operator is reminded of key techniques.

Micro computers provide the possibility of inter-active programmed learning whereby the user can respond to training material displayed on a visual display unit thus allowing a dialogue between the user and the programme. When coupled to a Viewdata system such programmes can be instantly updated.

A sophisticated refinement of such computerised systems is "Interactive Video" whereby a video system and computer is linked to give video based instruction to which the user can respond. Such systems are expensive in terms of hardware and training material but as technology improves and costs reduce they will become an important part of the training scene.

Despite advances in technology it seems likely that the key method of delivery to the agricultural and horticultural industry for the foreseeable future will be instructor based, generally off-the-job and delivered through training groups within the ATB structure.

CONCLUSIONS

If modern crop protection chemicals are to be applied safely and effectively operators must be trained. Such training should be provided according to clear relevant objectives through a delivery system which is relevant to the needs of the industry.

The ATB was established to ensure the provision of sound, economic and well organised training, on a national basis for all persons engaged in agriculture and horticulture in Great Britain. As part of this responsibility it will continue to develop and deliver the crop protection packages which are needed and to this end will work closely with relevant companies and bodies such as the British Crop Protection Council.

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A SYSTEM FOR CLASSIFYING HYDRAULIC NOZZLES AND OTHER ATOMISERS INTO CATEGORIES OF SPRAY QUALITY

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ABSTRACT

A spray classification system is proposed which divides the quality of spray produced by hydraulic nozzles and other atomisers into five categories. The system provides a simple, pragmatic method for relating the spray quality produced by different sizes and types of nozzles operated at different pressures. It enables advisers, users, product suppliers and registration authorities to describe the preferred way in which the product should be presented to the target and to determine the environmental safety of the proposed application.

Differences have been found between the cumulative volume curves produced by different droplet measuring systems for a given nozzle operated at a given pressure. When sprays are ranked in order of fineness, the order needs to remain the same for each measuring system. For this reason, spray qualities are classified by reference to standard nozzles representative of each category. BCPCwill approve droplet measuring systems, on which the cumulative volume curves for reference and test nozzles can be compared.

A nozzle description code is also proposed which details the nozzle type, spray angle, output and rated pressure.

INTRODUCTION

There is a need for the quality of spray produced by a nozzle to be easily and simply described. This would allow a better understanding of the likely effect on both efficacy of application and safety of using different sizes and types of nozzles at different pressures. (Elliot and Wilson 1983).

It is possible to measure the droplet size spectrum of a spray using a variety of measuring systems. The results are usually presented as a cumulative volume curve which shows the volume of spray contained in a range of size classes represented by an average droplet diameter.

This curve adequately describes the range of droplets produced in a spray. However, attempts to reduce the curve to a single figure introduce inaccuracies. For example, the Volume Median Diameter (VMD) describes the droplet size above which, and below which, equal volumes of spray are contained. However, it takes no account of the shape of the curve. Two sprays with equal VMD figures could have very different numbers of driftable droplets and very large droplets.

The term "span" produces a single figure which encompasses the droplet size below which 90%, 50% and 10% of the spray volume is contained.

$$\text{Span} = \frac{90\%\ \text{diameter} - 10\%\ \text{diameter}}{50\%\ \text{diameter}}$$

Again, this does not take full account of the shape of the curve.

These difficulties lead to the proposal to classify spray droplet spectra into five categories based on their whole cumulative volume curve between the 10% and 90% limits. (See "Definition of spray categories")

The pesticide user is often making a considerable investment in the products and spraying equipment, but is not always given detailed advice on the best type of spray to use. He is normally only informed of the dose and volume rates. The ability to describe a preferred spray quality, at any volume rate, will enable advisers, users, product suppliers and registration authorities to describe the preferred way in which the product is presented to the target and to determine the environmental safety of the proposed application.

It is accepted that for some products, precise spray quality recommendations will never be determined due to the flexibility and tolerance of the product and the complex nature of the crop or target. However, there have been examples of products where good evidence has been obtained to indicate that a particular spray quality is biologically or environmentally desirable or, conversely, undesirable. In these cases, phrases have appeared on labels attempting to inform the user - by specifying a minimum pressure, by recommending the actual nozzles to be used or by warning of drift or other hazards.

There has long been a tacit acceptance by product suppliers and registration authorities that most sprayers used for general arable spraying conform to a traditional standard using nozzles based on well known designs operating within reasonable limits of pressure and speed. This standard has performed adequately and safely and is universal, representing vast numbers of essentially identical sprayers. It is this standard which BCPC has adopted as the basis for the proposed spray classification.

This paper describes the system for classifying sprays and the use of that system. A handbook will be published by BCPC which will classify the sprays produced by nozzles and enable users to select and use nozzles to obtain the best spray quality for a particular situation.

BCPC SPRAY CLASSIFICATION

A number of spray classifications exist, but are not directly relevant to UK agriculture and horticulture nor to hydraulic nozzles. The relationship between droplet size, the number of droplets and volume rate has been discussed in many papers. (Matthews 1979).

The BCPC classification uses five simple, familiar, descriptive terms to describe the spray categories. They are: VERY FINE; FINE; MEDIUM; COARSE and VERY COARSE.

An important feature of the classification system is the ability to compare directly the spray spectra produced by different types and sizes of nozzle used at different pressures. Any category will, therefore, contain a mixture of flat fan, hollow cone, and other types of nozzle which, when operated at different pressures, produce very similar spray spectra.

Spray Categories

MEDIUM is the reference category. It is based on the spray produced by nozzles used in current general arable spraying - traditionally accepted by product suppliers and registration authorities. In general, this would coincide with volume rates from 200 litres per hectare to 330 litres per hectare at 2 to 3 bar pressure, normal speeds and nozzle spacing.

Other nozzle types and pressures producing sprays of similar quality would be placed in this category.

The FINE category ranges down to the finest spray commonly used in arable spraying. Its finer limit is carefully defined to avoid spray qualities which might present serious drift hazards.

The COARSE category represents sprays which are coarser than those normally used for general arable spraying. They would often be used for application to soil surfaces.

The VERY FINE category is for exceptionally fine sprays which would only be used where very clear evidence can be demonstrated of the biological need and product safety.

The VERY COARSE category is for exceptionally coarse sprays. A typical use would be liquid fertiliser application to soil and would often be associated with very high volume rates.

Label recommendations

The BCPC classification provides a simple, pragmatic means of communicating via the label to the user, the form of spray in which to apply the product. Product suppliers, and others making formal recommendations for use of pesticides, will be asked to consider their knowledge and experience of the product and target to see if any evidence exists for specifying a spray category other than MEDIUM. Greater choice can be offered to the user, if appropriate, by specifying two categories - for example MEDIUM or COARSE.

The preferred spray category will be indicated on the label as a simple phrase. For example, "Apply as a MEDIUM spray (BCPC definition)". The user will be able to find out from BCPC information (to be produced), his sprayer or nozzle supplier, product supplier or adviser which nozzles and pressures conform to the category. He will be able to set his sprayer for maximum efficacy and safety.

Where a specific recommendation for optimum performance can be identified, this should be stated, usually by specifying the preferred nozzles and pressures to be used.

BCPC NOZZLE CODE

The BCPC nozzle code details the nozzle type, spray angle (if known), output and rated pressure. It does not indicate spray quality because nozzles with the same physical description do not necessarily produce the same spray quality. Small manufacturing differences and different materials may affect spray quality - particularly with hollow cone nozzles. Also, nozzles may move from one category to another depending on the operating pressure.

The code has been developed to allow particular nozzles to be specified or described without using manufacturer's individual codes or terminology. The main use of the code will be to describe nozzles in a standard format so that they can be compared directly with each other and with manufacturers codes. For this reason, a standard rated pressure should always be used - 3.0 bar for normal hydraulic nozzle and 1.0 bar for low pressure nozzles. For specific purposes, where operating pressure is a critical factor, the pressure and the corresponding output may be stated.

Table 1

TYPE	SPRAY ANGLE	NOZZLE OUTPUT	RATE PRESSURE
Flat fan (F) (Note a)	Degrees (°)	litres per minute	(Note a)
Hollow cone (HC)	(Note b)	litres per minute	(Note a)
Deflector (D)	(Note b)	litres per minute	(Note c)

Notes: (a) F = triangular deposit flat fan - rated at 3 bar.

FE = rectangular deposit flat fan ("evenspray") - rated at 3 bar.

FLP = low pressure flat fan - rated at 1 bar.

HC = hollow cone - rated at 3 bar.

(b) To be specified if known.

(c) Deflector (anvil) nozzle normally rated at 1 bar.

Examples:

BCPC NOZZLE CODE	DESCRIPTION	NOZZLE OUTPUT LITRES PER MINUTE	RATED PRESSURE bar
F110/1.6/3	110° Flat fan nozzle	1.60	3.0
HC69/0.47/3	Hollow cone nozzle	0.47	3.0
D -/2.4/1	Deflector nozzle	2.40	1.0
FE80/1.83/3	80° "Evenspray" fan nozzle	1.18	3.0
FLP80/0.79/1	80° low pressure fan nozzle	0.79	1.0

DEFINITION OF SPRAY CATEGORIES

In order to determine the relationship between the spray quality of different nozzles at different pressures, it is, as has been described, necessary to consider their complete droplet spectra, between the 10% and 90% points on their cumulative volume curves. Outside these points the data become prone to increasing errors.

Measurement of droplet spectrum

Measurement of spray droplet spectra has been the subject of much debate in recent years (Arnold 1983, Young 1985). No one method has yet been shown to give a totally complete answer, and cumulative volume curves produced by different methods vary markedly.

A BCPC exercise has been undertaken to study various methods of measuring droplet size, using selected standard nozzles which were circulated to several collaborators who operate different measuring equipment. Fig A shows that the measured spectra can vary by ± 40% as indicated by their VMD's. The highest figures result from computer image analyser measuring droplets as their impression captured on a suitable sampling surface - magnesium oxide coated glass slide for the Optomax and a viscous fluid for the Biotran colony counter. The lowest figures are given by the Malvern laser operated analysers which sample spray clouds in flight passing through a thin laser beam, but using different computing processes to quantify the spectra to the PMS laser analyser.

Footnote - Optomax - Analytical Measuring Systems Ltd, Shirehill Industrial Estate, Saffron Walden, Essex.
Biotran - New Brunswick Scientific Co Inc, 44 Talmadge Road, Edison, New Jersey, USA.

Even within one method, differences can occur. Figure B shows that the Malvern analyser gave a difference of ± 12% depending on the model, all being used to the same protocol.

All these methods are commonly used and highly developed, producing valid results. However, these data highlight the problems of quoting definitive figures for droplet spectra.

Spray classification

It has been necessary to devise a method for dividing the ranking order into the spray categories which allows the use of different, suitable droplet sizing methods.

Three reference nozzles have been selected to be characteristic of the three main categories (FINE, MEDIUM and COARSE), representing approximately the mid-point of the range of spectra encompassed by each category (see Table 2). The thresholds between each category are not intended to be precisely defined, allowing a small degree of flexibility for judgement in classifying nozzles whose spectrum coincides with the threshold.

The threshold between FINE and VERY FINE has been more precisely defined by use of a fourth reference nozzle, which produces a spray characteristic of the finest sprays normally used in arable crop protection.

The VERY COARSE category is defined as sprays which are significantly coarser than the reference COARSE spray droplet spectrum.

Method of use

Selected examples of the four reference nozzles will be made available by BCPC to collaborating laboratories operating particle size analysers approved by BCPC for this purpose. In use, a reference chart will be constructed for each analyser by plotting the cumulative volume curves for the four reference nozzles operated at a specified pressure, following a BCPC protocol for that analyser. Regions equidistant about the three reference curves will determine the category areas except for the FINE/VERY FINE threshold which is defined by the fourth reference curve.

Droplet diameters equivalent to the 10%, 50% and 90% cumulative volumes will be measured for each test nozzle and superimposed onto the reference chart. It will be necessary to repeat the procedure for each test nozzle at several pressures to determine whether it moves into another category as the pressure is changed. See figure C.

In Table 2, the four reference nozzles are detailed using the BCPC nozzle code (the final figure is the pressure at which the nozzle must be operated).

Footnote – PMS – Particle Measuring System Inc. 1855,S.57 Court, Boulder, Colorado USA.
Malvern – Malvern Instruments Ltd, Spring Lane, Malvern, Worcs.

TABLE 2

CATEGORY		BCPC REFERENCE NOZZLES
VERY FINE		F110/0.45/4.5
FINE	F110/0.85/3.5	
MEDIUM	F110/1.44/2.5	
COARSE	F110/2.58/2.0	
VERY COARSE		

In table 3, further details of the reference and threshold nozzles are given. (Nozzle size, volume rate and droplet size data are purely representational).

TABLE 3

CATEGORY	NOZZLE SIZE (Note a)	PRESSURE (bar)	VOLUME RATE (litres/ hectare) (Note b)	DROPLET SIZE IN CUMULATIVE VOLUME (Note c)		
				10%	50%	90%
VERY FINE	01	4.5	82	35	85	195
FINE	02	3.5	145	50	145	325
MEDIUM	04	2.5	250	70	235	450
COARSE	08	2.0	420	110	340	580
VERY COARSE						

Notes

a. Nozzle 'size' is as used by Lurmark, TeeJet, Delavan - for information only.

b. Volume rate calculated at 7 km/h, 0.5 m nozzle spacing.

c. Droplet size data based on averaged readings from a Malvern 2600 particle size analyser, 600 mm lens, laser beam passing through long axis of fan at 12 cm. Spray liquid - water plus 0.1% Agral.

DISCUSSION

The BCPC spray classification and the nozzle code are intended to form the basis for a common language when discussing and using hydraulic nozzles and the sprays they produce. This will facilitate the assessment and implementation of both the efficacy and environmental safety of any proposed method of application. Product suppliers, users and registration authorities and users will be able to communicate more accurately and simply than has been possible.

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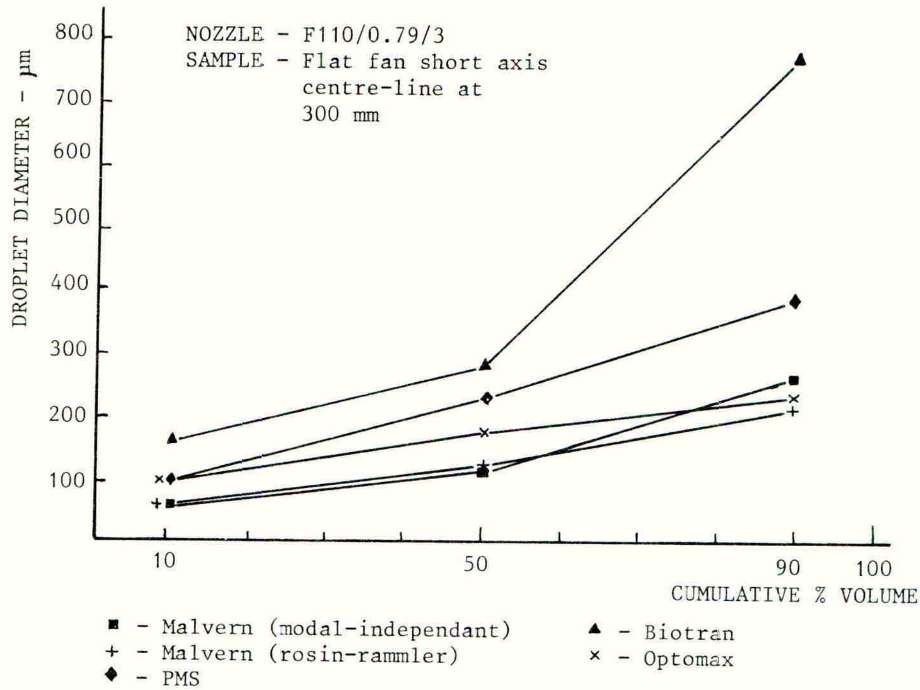

Figure A - Comparison of droplet sizing equipment.

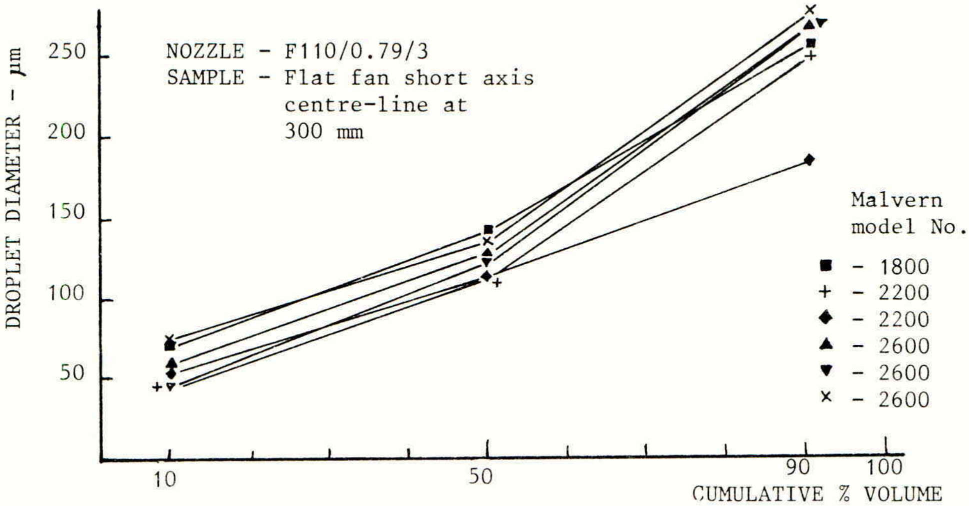

Figure B - Comparison of Malvern particle size analysers

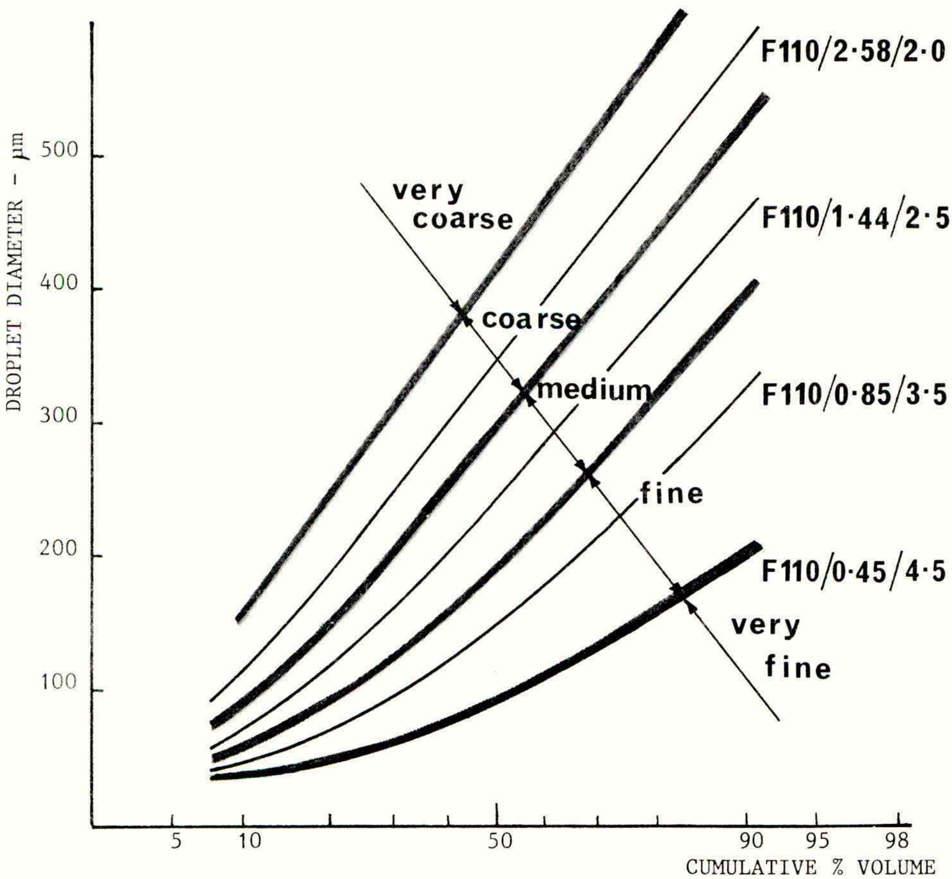

Figure C - Typical reference chart (for Malvern 2600 analyser)

ENVIRONMENTAL AND ECONOMIC CONSTRAINTS ON SPRAYING SYSTEMS

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ABSTRACT

In the past, crop protection research has concentrated on developing new chemicals rather than on the efficiency of pesticide application methods, so that today sophisticated formulations are frequently applied using relatively crude and wasteful machinery, causing financial loss and environmental damage. The environmental and economic constraints on pesticide use are summarised and it is argued that the emphasis of pesticide controls should be expanded from a concern with individual chemicals to include a more general appraisal of application methods. Whilst some improvements are likely to occur through financial incentives, individual spray users are not usually able to judge the wider effects of careless spraying, and increased use of the countryside for recreation and wildlife conservation is adding to pressure for tighter pesticide regulations. This concern is mirrored by all the political parties. A few of the additional regulations proposed during the Food and Environment Bill are briefly explained and the future role of "organic" farming assessed.

INTRODUCTION

Over the past few decades, the majority of research into pesticides has concentrated on the production of new and more sophisticated chemicals, both to replace those formulations rendered obsolete by pest resistance and to meet progressively more stringent safety regulations. The methods of pesticide delivery, on the other hand, have received far less attention; for example the spray nozzles usually used in hand-held or tractor mounted sprayers have remained essentially unchanged since the ninteenth century.

To some extent, this bias inevitably reflects the pre-occupations of the chemical companies themselves, who dominate the research field, and who obviously have little direct interest in reducing the sales of their products by improving the efficiency of chemical delivery. Nontheless, the lack of technical sophistication is still quite surprising given the number of research bodies operating in the field.

ENVIRONMENTAL AND ECONOMIC CONSTRAINTS

While research on formulations has improved both the safety and efficacy of pesticides, there are still aspects of current chemical use which suggest that several important problems still remain. These fall into three main areas:

(1) Safety of pesticides

Safety is still frequently the subject of public and professional debate. The piecemeal nature of legislation, combined with the continued use of chemicals in Britain which have been banned or severely restricted in other countries, such as amitrole, aldrin, chlordane, gamma HCH, nitrofen, pentachlorphenol and others (Anon 1984), has created a public disquiet about the effects on health of many agrochemicals. This debate has been increased recently, partly as a result of the publicity surrounding the Food and

Environment Protection Bill and partly because of campaigns by Friends of the Earth and other environmental groups.

Although the debate about safety has been highlighted by the environmental lobby, spray operators themselves are probably the most at risk. A survey carried out from the Open University of eighty farmers found that over half believed that they had suffered ill effects from chemicals, but that only one had bothered to report this (Tait 1985). Whilst it is not the purpose of this paper to examine pesticide safety in detail, there are strong arguments for minimising the contact that humans (and wildlife) have with agrochemicals.

(2) Pesticide resistance

The number of pests becoming resistant to one or more pesticide has increased rapidly over the last ten years (Dover and Croft 1984). It is also becoming increasingly expensive to formulate new pesticides, partly because the simplest and cheapest have often already been "burned out" and partly because of the stricter safety regulations which now exist. This gives manufacturers a shorter time to recover development costs and has encouraged some firms to return to broader action pesticides to maximise their profits on each product; these broad action chemicals are usually more damaging to wildlife.

(3) Rising costs

These additional constraints on agrochemicals come at a time when the existence of agricultural surpluses in Europe and controversy over the Common Agricultural Policy have caused politicians of all parties to question the amount of subsidy available to farming and forestry. Some farming organisations fear a repeat of the problems facing small farms in the USA. Whilst it is dangerous to attempt the prediction of rural futures, a general point can be made that there are intensifying financial incentives to reduce avoidable pesticide losses.

This means that there are both environmental and economic reasons to minimise the amount of pesticide which is deposited away from its target. Environmental pressures focus on the potential hazards to people (Rose 1985), wildlife (Anon 1985), and the environment, while economic penalties of excess pesticide use include the costs of wasted chemical, the possibility of damage to neighbouring crops and livestock (Elliott and Wilson 1983) and the more general problem of pest resistance which, broadly speaking, is likely to increase with the amount of a particular formulation applied (Dover and Croft 1984). These factors are summarised below in Fig. 1.

THE CHANGING FOCUS OF PESTICIDE CONTROLS

Until recently, the emphasis of individuals and groups lobbying for greater pesticide safety has been on the type of pesticide used, perhaps partly in response to the weighting given to this aspect by the industry. The majority of legal constraints have been aimed at restricting or banning specific formulations rather than controlling the methods in which they are applied, apart from very basic safety requirements. Whilst monitoring and control of individual chemicals will continue to be essential in the future, there is an increasing realisation that this is only one facet of chemical farming requiring attention. Given the continued use of pesticides in the future, (although it will be argued later in this paper that the amounts used could be reduced substantially), along with the potential danger of incorrectly used agrochemical, means that there is a strong case for putting greater effort into the safety with which all of these are applied.

FIGURE 1

Environmental and economic constraints on pesticides

	people
Environmental constraints	wildlife
	long-term build up
	inefficient use
Economic constraints	damage to others crops
	increased pest resistance

From the environmental perspective, this presents two main questions. First, are increases in safety and efficiency possible, and secondly can the industry be expected to introduce them wholly as a result of the economic incentives listed earlier, or will additional legislation be needed ? These two points will be examined in turn.

EFFICIENCY OF PESTICIDES

It might appear to be a truism that the amount of pesticide applied to a crop should be reduced to the minimum necessary for adequate crop protection. However, this has manifestly not been the case in practice and there has been a growing realisation over the last decade that pesticides are usually applied with gross inefficiency.

Research using computer and laser technology has shown the existence of a greater proportion of droplets less than 100 microns in diameter being produced by conventional hydraulic spray nozzles than was previously believed (Matthews 1982). These drops are prone to drift and increase waste, although more significant losses come from very large drops, which tend to bounce off crops or at best give a large overdose. In a widely quoted paper to the Royal Society in 1977 it was claimed that rather less than 1 per cent of an insecticide usually reaches the insect pest and that even if foliage itself is the target, up to 70 per cent of the spray will be lost during application (Graham-Bryce 1977). Concurrently, the wide publicity given to spray and vapour drift damage to agricultural crops showed that inefficiency could result in positive damage as well (Elliott and Wilson 1983). Even if the figures for losses were pessimistic, the costs of undervaluing the importance of application efficiency are obviously quite severe.

Indeed, far from improving over the past few years, there is evidence that the problems have actually increased as a result of increased boom height (Combellack 1982), spray pressure (Combellack and Matthews 1981) and changes to the type and angle of atomiser (Arnold 1983). These inefficiencies have already been extensively reviewed (Matthews 1982). They have added impetus to the development of theoretically more efficient systems, such as controlled droplet application and electrostatic spraying. It does now seem possible that these and other improved technologies will gain wider acceptance in the near future.

ECONOMIC INCENTIVES FOR IMPROVING PESTICIDE EFFICIENCY

There is an argument that even from a strictly economic point of view, conditions within the agricultural community are now conducive to a gradual increase in pesticide application efficiency and hence an increase in safety. The recent response of the National Farmer's Union in suggesting a voluntary ban on ester herbicide formulations shows that when direct agricultural interests are threatened the farming establishment can move quite fast to make improvements. From the long term perspective of a desire for good relations between farmers and conservationists, most environmental groups would probably favour self regulation whenever possible.

Unfortunately, there are several problems inherent in relying solely on economics to provide adequate environmental controls. These include the possibility of a long time lag between new innovations and their widespread adoption by the majority of spray users and, more importantly, the shortcomings inherent in relying wholly on the narrow financial criteria applied by individual pesticide users as a measure of the overall cost effectiveness of improved application efficiency.

Awareness of application efficiency, chemical hazards and the importance of spraying techniques varies very considerably within the industry; this has been illustrated in some arable regions by the large number of pesticide drift incidents onto neighbouring crops, private gardens and public roads (Dudley 1984). Many farmers and growers have little contact with ADAS advisers, or exposure to points of view that are cautious about pesticides, since they rely wholly on sales representatives for advice. However well meaning the latter may be, they are unlikely to overstress the hazards of chemicals which they are employed to sell. Moreover spray operators often show a surprising lack of knowledge about safety precautions, judging from interviews conducted during our research. The comparative isolation of many users from the mainstream of innovation will inevitably slow down the rate with which potentially safer techniques and equipment are adopted.

A much more serious problem is caused by relying on the financial incentives directly relating to the pesticide user alone to determine whether it is "worth" investing in new machinery or methods. This can result in a distorted perspective where many important "costs" are left out altogether, including factors like wildlife destruction, broader health issues and damage to other crops. Since these cannot usually be ascribed a precise numerical cost they are likely to be missed altogether, or at best substantially undervalued.

Even the economics of the agricultural community may show marked divergences from the short-term financial incentives of the individual producer, such as the cases of spray drift damage to neighbouring crops or when overuse of a pesticide hastens resistance to the chemical. These differences are even more marked when the interests of the public or local authority are in conflict with crop spraying. A recent example of this is the argument about aerial crop spraying, which has spilled out into parliament with members from all parties calling for a ban. The debate has been outlined in detail elsewhere (Dudley 1985) and the relative safety of spraying from the air is less important here than the fact that the economic calculations of the farmer, who decides it is worth hiring a plane, may be in direct opposition to local people who perceive it as an unacceptable risk. There are now a considerable number of documented cases of health effects arising from aerial spraying incidents (ibid) and the person using the spray may have a different judgement of its cost-effectiveness than that of people living nearby.

In the last few years, traditional rural activities like farming and forestry have been joined by others, mainly connected with tourism and leisure. This brings increasing numbers of visitors to the countryside with their own wishes and requirements, as well as providing an important source of income for many rural dwellers. The public, via taxation, have long subsidised food production in Britain; it may now be that returns in the form of greater environmental protection are required by enough people to make this politically acceptable. Many people are questioning the wissom of subsidising intensive agriculture to produce food surpluses, or to put it another way, are questioning the current economic criteria used as justification for the cost effectiveness of intensive farming, including pesticide use at current levels.

An attempt at rather broader accounting may be necessary, including both economic and environmental costs as outlined above, many of which are not usually assigned a financial cost, (and indeed where it might be very misleading or even impossible to do so). A summary of what the expanded balance sheet might look like is given in fig. 2; the headings given are not comprehensive and would not all be expected to apply in every case of pesticide use, and indeed some may be very rare.

FIGURE 2

Proposal for a pesticide balance sheet, including economic and environmental factors

Financial costs to the:			Non-financial costs to:
SPRAYER	AGRICULTURAL COMMUNITY	PUBLIC	
chemical	damage to other crops	wildlife loss *	wildlife
equipment	damage to livestock	health care	health problems
	pest resistance	policing	environmental damage
labour		regulations	
		farming support	
		research +	
		pollution control	

Notes * = through state support of conservation
+ = through university faculties and government departments

The financial costs per spray application are likely to be greatest for the spray operator or contractor, who also gets the financial rewards. However, the cumulative cost to the public and the state of inefficient spraying methods has never been adequately calculated.

Individual spray operators are not usually to blame for these anomolies as they have been encouraged by successive governments to maximise production wherever possible. However, there is a growing realisation that environmental considerations will play an increasingly important part in determining the structure of British farming, forestry and local council management in the future. Whether producers will be subsidised to grow less, in a more environmentally benign way, or simply face reduced subsidies and competition from cheaper imports, will ultimately depend on political considerations and it is very difficult to judge what any of the British political parties, or the EEC, will decide in the future.

CONSTRAINTS ON PESTICIDE USE

This paper has argued for the need to improve the efficiency of pesticide use and the necessity for this to be, at least to some extent, controlled by law. It is difficult to judge exactly what new legislation will be required until the Food and Environment Bill has become law and been in operation for some time. However, it may be useful to summarise some of the suggestions which have emerged from discussions within the environmental lobby and the main points are given briefly below; these are summarised from two reports published by the Soil Association (Thorpe and Dudley 1984, Dudley 1985).

(1) A ban on existing wide spray spectrum nozzles, phased over a number of years, accompanied by the introduction of safer systems, probably CDA or similar. Standards for spray nozzles should insist on a safe spectrum of droplet size production for all applications. Recent research in Australia suggests that droplets of below 100 microns are the least efficient in terms of impaction on vegetation (Dubs et al 1985).

(2) Obligatory labelling of chemicals with recommended droplet size and measuring applications in droplets per square centimetre rather than gallons per acre.

(3) Inclusion of safety details, including evidence of side effects to human health and wildlife, on the label, which should be firmly attached to the chemical container.

(4) Obligatory addition of drift inhibiting vegetable oils, or other safe additives, to chemicals sprayed in a water medium

(5) An official ban on ester formulation herbicides to reduce the risk of vapour drift damage to surrounding crops.

(6) Restriction of aerial spraying to bracken clearance and forestry operations in sparsely populated areas.

(7) The formation of an independent regulatory body to assess pesticide data, which will remain the confidential property of the regulatory body. This body should have official links with the Departments of Environment and Health and Social Security as well as the Ministry of Agriculture Fisheries and Food, and would avoid the confusion caused by the current parallel schemes.

(8) Introduction of a mandatory training programme for all spray operators using pesticides for commercial purposes, including details of safety and environmental impact and requiring an adequate pass mark in an examination before a license is awarded. Alternatively there could be a requirement for at least the supervisor of a team to have received training.

(9) The establishment of a central compensation fund for people suffering from pesticide side effects, either to their crops or their own health, financed by a direct levy on agrochemical manufacturers and users.

(10) More research into the wildlife effects of pesticides, and particularly the potential for leaving unsprayed edges and corners as refuges for insects and wild birds as is currently being assessed by the Game Conservancy and the British Trust for Ornithology.

This outline list is by no means a comprehensive survey of the suggestions coming from environmental groups over the past two or three years, nor would all the organisations necessarily support all the points made above. It does give some idea of where the debate may be developing in the future and it should be noted that many of these points would be unlikely to emerge from spray users alone in the near future, although hopefully many will be advantageous to both pesticide users and others living in the country.

ORGANIC[1] FARMING: A MORE RADICAL APPROACH TO PESTICIDES

By keeping within the brief of this conference, I have concentrated on improvements to pesticide use within the general constraints of intensive chemical farming. There are a growing number of farmers and market gardeners who have dispensed with pesticides either virtually or completely; while their numbers are still small, sales of pesticide-free produce is increasing rapidly, with many shops stocking it as an option and a network of wholesale warehouses being established in Britain. The knowledge and expertise of organic growers is being refined, despite the lack of government funding for this area of agriculture.

Organic farming uses many different techniques and skills from those employed in chemical farming and there is still a great deal of research required, but the increasing success and sophistication of the pioneers means that it has now moved away from fringe participation into an increasingly important area. These developments have a number of implications for conventional farming which are worth outlining briefly in the context of spraying systems.

First, the existence of organic or low input farms alongside conventional systems will necessitate much tighter controls on the spread of any agrochemical away from the target area. Growers relying on knowledge of a system without pesticide input will find their calculations badly upset by spray drift, while customers paying a premium for pesticide free food have a right to be able to purchase this, whatever surrounding growers think of the merit of this.

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[1] "organic" is an unfortunate name; as used here it refers to growing with minimum or zero artificial pesticides and fertilisers. It does not refer to organic in the strictly chemical sense.

Secondly, some observers believe that there will be a corresponding move towards so-called "low input" farming, where a balance between completely organic and intensive chemical farming is made, reducing pesticides and artificial fertilisers to a bare minimum and having a slightly lower yield in consequence, but not abandoning the option of agrochemicals in cases of serious pest infestation. Changing economic conditions and agricultural subsidy may make this an attractive option in the future.

There is also likely to be an increasing pressure for research into alternative pest control methods, including the various types of biological control, mechanical methods and flame techniques; these may eventually be taken up by existing companies (as is already the case to some extent) but could also bring new firms and interests into the field.

In the longer term there may be more fundamental changes in attitudes. For example, some people now prefer to buy fruit and vegetables with blemishes than to purchase perfect looking produce which has been kept immaculate with spray applications. A more general shift in public tastes could alter the profitability of much cosmetic spraying. It could also affect imports, because pesticides are often used far less carefully in the Third World than they are in Britain. Individuals growing food in their gardens may wish to ensure that neighbours or councils do not allow chemical sprays to enter their property. Whilst these changes may well be gradual and fragmentary, the ability to be able to control pesticide applications far more precisely is likely to increase still more in the future.

ACKOWLEDGEMENTS

I am indebted to the Soil Association for allowing research carried out for them to be used in the preparation of this paper.

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