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THE EFFECT OF SEVERAL HERBICIDES ON MOSS ESTABLISHMENT IN ORCHARDS

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Summary Although overall herbicide soil management can increase the productivity of fruit trees its use in commercial practice may be limited by practical problems such as erosion on some soil types. A bryophyte cover seemed to reduce soil loss and increase soil water holding capacity. In experiments at both East Malling Research Station, Kent and the Horticultural Centre, Loughgall, Armagh, moss establishment was affected by the herbicide used. Moss cover, mainly Bryum argenteum, was most extensive with simazine and absent or almost absent with aminotriazole or diuron.

INTRODUCTION

Fruit trees are usually grown in a herbicide-treated strip with a grassed alley. Grass is used because of its beneficial effects on soil structure and to protect the soil surface against the adverse effects of rain and machinery movement. However, recent studies have shown that growing apple trees under overall herbicide management rather than in a wide herbicide strip increased cropping by 40% (Atkinson and White, 1980). This appears to result from the elimination of competition for soil water (Farré, 1979). Although overall herbicide soil management can increase cropping, its wide-spread adoption in commercial practice will depend upon its practicability. A survey of commercial fruit growers' experiences with overall herbicide showed the main difficulties to be: 1) soil erosion, 2) problems with machinery movement, particularly during wet harvest times, 3) possible risk of increased Phytophthora fruit rots (Atkinson and White, 1977). These problems are at least partially due to an uncovered soil surface which is open to physical disruption by raindrop impact and which may be less capable than a grassed surface of recovery.

Experience at East Malling and elsewhere suggests that where the soil surface is covered by moss, problems are reduced. Factors influencing the establishment of moss in orchards are poorly understood. This paper describes trials initiated by the ARC Fruit Weed Control Group on the effect of different herbicides on moss establishment.

METHOD AND MATERIALS

Experiments were carried out at East Malling Research Station, Maidstone, Kent and the Horticultural Centre, Loughgall, Armagh, N.Ireland. The whole of the experimental area was cultivated initially and plots (1 x 1 m at East Malling, 2 x 2 m at Loughgall) laid out in a randomized block design. Treatments were replicated six times at East Malling, four times at Loughgall. All herbicides were applied annually in March or April at approximately commercial rates to individual plots. The chemicals used are shown in Table 1.

Table 1

The herbicides applied to the two sites.
(E = East Malling; L = Loughgall).

	Herbicide	Rate kg ha^{-1} a.i.	Site
1)	Aminotriazole	4.5	E, L
2)	Bromacil	2.3	E, L
3)	Chlorthiamid	9.2	L
4)	Dichlobenil	9.2	E, L
5)	Diuron	3.2	E, L
6)	Glyphosate	2.5	E, L
7)	Propyzamide	1.7	E
8)	Simazine	2.2	E, L
9)	Simazine (x3 dose)	6.6	E, L

On all plots weed growth not controlled by the treatment herbicide was treated with paraquat as necessary. Treatment began in April 1976 at Loughgall and a year later at East Malling. Chemicals were applied until 1980 at Loughgall, but only until 1979 at East Malling. Moss establishment was recorded annually. At Loughgall moss cover was scored in the centre $1m^2$ of the plots using a 0-10 scale (0 = no moss, 10 = complete cover; intermediate values approximately 10 percent cover units) in June/July during 1978-80. At East Malling moss was scored as present or absent until May 1980 when it was recorded as percentage cover using a point quadrat with a 0.3 mm diameter point. At both sites the species present were identified.

At East Malling only, the change in the level of the soil surface, relative to that at the beginning of the experiment, was measured in June 1980. The resistance to a soil penetrometer (Farnell, Hatfield), with a 20 mm basal diameter, 314 mm^2 basal area cone, was measured on simazine and diuron treated plots. The gravimetric water content ($g\ g^{-1}$ dry soil) of the surface 50 mm of soil was measured on 3 bulked cores taken from the simazine and diuron-treated plots approximately 24h after heavy rainfall.

RESULTS

Moss establishment was first recorded at Loughgall in 1978, two years after the beginning of the trial, but at East Malling within the first year of the experiment.

Table 2

The effect of different herbicides on the ground cover by mosses at East Malling in May 1980.

	Herbicide	% Cover
1)	Aminotriazole	4
2)	Bromacil	38
4)	Dichlobenil	12
5)	Diuron	0
6)	Glyphosate	28
7)	Propyzamide	18
8)	Simazine	45
9)	Simazine (x3 dose)	49
	Standard Error	3

Treatment effects significant at P = 0.001

For East Malling the percentage of the ground surface area covered by moss is shown in Table 2. Cover was under 50% on all plots. This apparently low cover would result partly from the use of a small diameter point quadrat. Moss cover was highest for plots treated with simazine, intermediate with bromacil and glyphosate, low for aminotriazole, dichlobenil and propyzamide and absent with diuron. There was no difference between the plots treated with different rates of simazine. Results from Loughgall were generally similar to those from East Malling (Table 3). Establishment was best with simazine and glyphosate and absent with aminotriazole and diuron. Bromacil had a greater adverse effect at Loughgall compared with East Malling.

At both sites the dominant moss species was *Bryum argenteum* but there was also some *B. caespiticium* and *B. bicolor* at East Malling and *Funaria hygrometrica* at Loughgall. The herbicide treatments did not seem to affect species composition although where only small amounts of moss were present this was usually *B. argenteum*.

Table 3

The effect of specific herbicides on mean ground cover by mosses at Loughgall (index 10 = complete cover) in mid-summer of 1978, 1979 and 1980.

Herbicide	Establishment Index 1978	1979	1980
1) Aminotriazole	0-1	0	0-1
2) Bromacil	1	0	2
3) Chlorthiamid	1	1	0
4) Dichobenil	2	2	3
5) Diuron	0	0	0
6) Glyphosate	5	4	5
8) Simazine	7	7	8
9) Simazine (x3 dose)	5	6	5

The effect of a moss cover on resistance to erosion, water-holding capacity and surface compaction is shown in Table 4.

Table 4

The effect of specific herbicides on a) the change in the height of the soil surface (mm) over the 3 years of the experiment b) soil water holding capacity (g g^{-1} DW) and c) resistance to a penetrometer (Cone Index Values : high values more compact).

Herbicide	Change in soil surface level	Water content	Resistance to penetrometer
1) Aminotriazole	-31	-	-
5) Diuron	-32	0.164	59
6) Glyphosate	-20	-	-
8) Simazine	-17	0.180	48
9) Simazine (x3 dose)	-20	-	53
Standard Error	7	0.007	5

Treatment effects significant at P = 0.05 or greater

The data suggest that as a result of the moss cover developed under simazine erosion was reduced, and the fall in soil level was smaller but there was little effect on soil resistance. The soil water content was higher under moss.

The effects of moss on soil water depletion needs to be assessed. Data for changes in soil water potential under both moss covered areas and adjacent areas kept moss free by the use of copper sprays at East Malling (Table 5) showed that water potentials were as high or higher under moss. There was some evidence, lower potentials following rain, e.g. 22 August, 12 September, of reduced penetration in the absence of moss.

Table 5

The soil water potential (-KPa) at 0-10 and 10-20 cm depth at intervals during 1975 under moss-covered and bare soil plots.

		Date			
Treatment	Depth	9 July	25 July	22 Aug	12 Sept
Moss	0-10	37	29	6	21
Bare	0-10	40	40	10	32
Moss	10-20	18	19	7	26
Bare	10-20	16	21	16	27

DISCUSSION

The regular production of high yields of high quality fruit is of critical importance for successful fruit growing. The presence of other vegetation in either the alleyway or in the herbicide strip greatly affects the growth, cropping and quality of fruit produced (Atkinson and White, 1976, 1980, 1981; Atkinson and Lipecki, 1981). Herbicide management can result in problems with erosion and reduced infiltration of rainfall into the soil profile. Gurung (1979) showed that infiltration was reduced on an overall herbicide plot compared with one under grass or where the soil surface had been protected by straw or stabilized by the remains of herbicide killed vegetation. Tree growth was also reduced. Observations in orchards and the data presented here (Table 4) suggest that the establishment of moss in an orchard will reduce erosion. Whether the higher water content of the surface soil from the moss-covered simazine-treated plots (Table 4) was due to a better infiltration of rainfall or an alteration of the soils' inherent water-holding capacity was not determined.

Moss can establish on soil either from vegetative propagules (gemmae or detached shoots) or from spores via the growth of protonema. The relative importance of these in the colonization of orchards is unknown although the establishment and development of cover are influenced by the herbicide selected (Tables 2 and 3). Establishment was adversely affected (relative to simazine) by both soil acting (residual) materials, e.g. diuron and by foliage acting materials, e.g. aminotriazole with effects present 12 months after the last spray. Studies of the mechanisms of these effects would be of value. Where moss establishment is considered advantageous care should be taken in selecting herbicides to be used and aminotriazole and diuron avoided. The effects of these chemicals on established Bryum argenteum and other acrocarpus mosses is not known.

The case for the removal of grass from the orchard is based on reduced competition for water. Results presented here (Tables 4 and 5) suggest that water deficits under moss will be no higher than those under bare soil and might even be slightly lower.

A cover of moss on the soil surface therefore seems desirable and is influenced by the method of herbicide management.

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THE EFFECT OF AUTUMN APPLICATIONS OF GLYPHOSATE ON FRUIT TREE SUCKER CONTROL AND ON PARENT TREE DAMAGE

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Summary. Previous trials showed spring and summer applications of glyphosate killed suckers without damaging parent trees, but that some ornamental *Malus* pollinators were susceptible to glyphosate applied to branches in autumn. To check the susceptibility of fruit tree cultivars to autumn applications, glyphosate was applied to sucker and distal branch units of apple, pear and plum to assess sucker control and parent tree damage.

Applications to suckers killed those sprayed and reduced the number and height of new suckers the following year, without causing damage to the parent tree.

In Cox's Orange Pippin apple, Victoria plum and Williams' Bon Chretien pear only the branch sprayed with glyphosate was damaged. In Kidd's Orange Red apple distal branch application killed the sprayed part and severely damaged other parts of the tree the following year. The differences in susceptibility of fruit and ornamental *Malus* cultivars to autumn applications of glyphosate is discussed.

Résumé. Des essais précédents ont montré que les applications printanières et estivales de glyphosate ont tué des rejets sans causer de dégâts aux arbres-mères, mais que certains pollinisateurs ornamentals du genre *Malus* étaient sensibles au glyphosate appliqué aux branches en automne. Pour vérifier la susceptibilité des cultivars des arbres fruitiers aux applications automnales, le glyphosate a été appliqué aux rejets et aux éléments des branches distales de pommiers, poiriers et pruniers pour évaluer les résultats contre les rejets et les dégâts aux arbres-mères.

Les applications aux rejets ont tué ceux qui ont été pulverisés et ont réduit le nombre et la taille des rejets nouveaux de l'année suivante, sans causer de dégats a l'arbre-mère.

Chez le pommier Cox's Orange Pippin, le prunier Victoria et le poirier William's Bon Chrétien, seulement la branche pulverisée avec glyphosate a été endommagée. Chez le pommier Kidd's Orange Red, les applications aux branches distales ont tué la partie pulverisée et causé de graves dégâts a d'autres parties de l'arbre dans l'année suivante. Les différences de susceptibilité entre les cultivars fruitiers et ornamentals du genre *Malus* aux applications de glyphosate en automne sont discutées.

INTRODUCTION

Glyphosate is a valuable broad spectrum herbicide (Bailey and Davison 1974 and Seddon, 1974), and its use in top fruit is increasing. It is readily translocated and is resistant to metabolic degradation in fruit trees (Putnam, 1976) and weeds (Gottrup et al, 1976). The severity of damage to fruit trees has varied notably with the time and target of application (Davison, 1975). Stapleton and Buster, 1976 and Atkinson et al, 1978 found that spraying trunk and suckers of fruit trees during winter, spring or summer caused no damage to the parent trees and gave some control of suckers. Similarly, winter, spring or summer application to lower branches of fruit trees made to assess the hazard of spray drift resulted in local damage, but no evidence of translocation to other parts of the trees (Stott and Harper, 1974 and Stinchcombe and Stott, 1978). However, more recently growers have reported that autumn spraying caused extensive damage to Malus pollinators in the following spring and our experimental trials confirmed that some but not all Malus pollinators were indeed susceptible to glyphosate when applied in autumn to lower branches (Stinchcombe and Stott, 1978). Hence the present experiment was designed to examine the general susceptibility of apple, pear and plum cultivars to autumn applications of glyphosate to rootstock suckers and to distal branch units and to assess sucker control and parent tree damage.

METHOD AND MATERIALS

The experimental material comprised mature trees of Cox's Orange Pippin and Kidd's Orange Red apple on M7; Williams' Bon Chretien pear on quince A and Victoria plum on St.Julian A. The average number of 1-2 year old suckers present around each tree were; Cox's 14, Kidd's 10, Williams 31 and Victoria 49.

On the 11th October 1978 when both sucker and tree leaves were beginning to senesce, glyphosate [N-(phosphonomethyl)glycine] was applied at 2.4 kg a.e. in 450 l of water to run-off to the following:

1) the lower 10-15 cm of all the suckers around the base of the trees; (tree trunks were also wetted during spraying)

2) the distal 20 cm of a single lower branch

Treatments were applied to 4 single tree replicates of Kidd's, 10 of Cox's and Williams and 13 of Victoria. An equal number of trees with suckers were left unsprayed as controls. Sprayed and unsprayed trees and suckers were examined during the spring and summer 1979. Sucker growth was assessed in July 1979 by recording the number and height of dead and healthy suckers around each tree and also the number and height of all new (i.e. 1979) suckers.

For both sucker and distal branch treated trees, tree responses were assessed by recording in May 1979 the number of blossom clusters per metre of branch on 4 branches per tree and in July 1979 the shoot extension growth on 6 branches per tree. Additionally for distal branch treated trees of Cox's and Kidd's, all blossom clusters were counted on 4 sprayed and 4 unsprayed trees.

RESULTS

Effect on suckers

Table 1 shows that autumn applications of glyphosate to fruit tree suckers killed all suckers sprayed and significantly reduced the height and number of new suckers in spring 1979. Most of the new suckers showed signs of glyphosate damage; chlorotic leaves, reduction in leaf size and uprolled margins.

Table 1

The effect of glyphosate on suckers sprayed October 1978

Cultivar, rootstock and tree age in brackets	No. of replicate trees	Treatment	Sprayed suckers October 1978 No. of suckers (per tree)	Sprayed suckers October 1978 Mean ht. (cm)	Sprayed suckers July 1979 Dead suckers %	Sprayed suckers July 1979 Mean ht. (cm)	New suckers July 1979 New suckers (per tree)	New suckers July 1979 Mean ht. (cm)
Williams' Bon Chretien on Quince A (19)	10	Sprayed	29.0	47.6	100	47.7	3.1	13.2
					**	**	**	**
	10	Unsprayed	32.8	49.6	16	76.6	19.6	40.0
Cox's Orange Pippin on M7 (17)	10	Sprayed	13.5	54.5	100	54.8	1.0	10.0
					**	**	**	**
	10	Unsprayed	12.4	54.2	3	79.7	6.6	29.7
Kidd's Red on M7 (17)	4	Sprayed	14.6	57.2	100	57.8	0	0
					**	*	**	**
	4	Unsprayed	16.3	55.2	0	71.8	6.6	43.5
Victoria on St. Julian A (7)	13	Sprayed	29.0	56.6	100	57.1	6.2	17.9
					**	**	**	**
	13	Unsprayed	21.3	59.8	0	89.1	15.4	43.9

* difference significant at the 5%, ** at the 1% level

Spraying the distal branch units did not affect suckers; none were killed and growth throughout 1979 was normal. (Table 2)

Table 2

The effect of glyphosate sprayed in October 1978 to distal branch units on sucker growth and number

		October 1978		July 1979		New suckers July 1979	
Cultivar and rootstock	Treatment	No. of suckers (per tree)	Mean ht. (cm)	Dead suckers %	Mean ht. (cm)	New suckers (per tree)	Mean (cm)
Williams' on Quince A	Sprayed	21.1	41.8	0	71.6	17.8	40.0
	Unsprayed	29.8	49.6	0	76.6	15.6	38.0
Cox's on M7	Sprayed	10.0	54.3	0	78.0	5.6	27.9
	Unsprayed	12.4	54.2	0	79.7	6.6	29.7
Kidd's on M7	Sprayed	13.7	52.9	0	69.0	5.9	45.6
	Unsprayed	16.3	55.2	0	71.8	6.6	43.5
Victoria on St. Julian A	Sprayed	17.5	53.6	0	97.7	14.1	47.2
	Unsprayed	21.3	59.8	0	89.1	15.4	43.9

Differences not significant

Effect on parent trees

Spraying glyphosate in autumn onto suckers did not lead to damage to the fruit trees the following spring. Table 3 shows that blossom density (blossom cluster count/m of branch) and shoot extension were not affected.

Table 3

The effect of glyphosate sprayed October 1978 to suckers on parent tree growth and flowering

		May 1979	
Cultivar and rootstock	Treatment	Mean blossom cluster count (per m of branch)	Mean extension growth (cm)
Williams' on Quince A	Sprayed	30.1	29
	Unsprayed	27.7	28
Cox's on M7	Sprayed	17.3	66
	Unsprayed	15.0	64
Kidd's on M7	Sprayed	15.9	63
	Unsprayed	15.6	61
Victoria on St.Julian A	Sprayed	31.3	24
	Unsprayed	31.2	25

Differences not significant

Table 4 shows that in most of the apple, pear and plum cultivars examined, spraying the distal 20 cm of a lower branch with glyphosate only killed the treated area. Blossom density and shoot extension growth the following spring in other parts of the trees were not affected. Kidd's Orange Red was exceptional - blossom density and shoot extension in other parts of the trees were reduced and so the more detailed whole-tree assessments presented in Table 5 were done.

Table 4

Effect of glyphosate sprayed in October 1978 to distal branch units on tree blossom counts (per m branch) and growth

Cultivar and rootstock	Treatment	Blossom cluster counts May 1979 (per m branch) Sprayed branch	Blossom cluster counts May 1979 (per m branch) Unsprayed branch	Mean extension growth July 1979 (cm) Sprayed branch	Mean extension growth July 1979 (cm) Unsprayed branch
Williams' on Quince A	Sprayed tree	0	30.0	0	29
			ns		ns
	Control tree	-	29.0	-	30
Cox's on M7	Sprayed tree	0	15.2	0	64
			ns		ns
	Control tree	-	15.0	-	65
Kidd's on M7	Sprayed tree	0	11.9	0	55
			*		**
	Control tree	-	15.6	-	61
Victoria on St.Julian A	Sprayed tree	0	30.5	0	27
			ns		ns
	Control tree	-	31.2	-	25

* difference significant at the 5%, ** at the 1% level
ns - not significant

Table 5 shows that in Cox both sprayed and unsprayed trees had a similar number of blossom clusters and the same extension growth and that although the sprayed branch was killed (no blossom) a nearby unsprayed branch had a similar blossom density (15.2) to that of a branch from an unsprayed tree (15.0). But in Kidd's Orange Red distal branch applications completely killed the sprayed part of the branch <u>and</u> caused severe damage to other parts of the tree. The affected branches were shorter (Table 5) and produced small cup shaped chlorotic leaves, and no blossom. Table 5 shows that by comparing whole trees, or unsprayed sample branches, glyphosate sprays caused a 25% reduction in blossom density.

Table 5

Effect of distal branch applications of glyphosate on blossom density and shoot growth of 2 apple cultivars

Cultivar and rootstock	Tree treatment (1978)	Total No. blossom cluster counts per tree May 1979	Mean extension growth 1979 (cm)	Branch assessment 1979	Mean no. of blossom cluster counts per m branch May 1979
Cox's on M7	Sprayed	1060	64	Sprayed	0
				Unsprayed	15.2
		ns	ns		ns
	Unsprayed	1104	65	Unsprayed	15.0
Kidd's on M7	Sprayed	723	55	Sprayed	0
				Unsprayed	11.9
		**	**		*
	Unsprayed	983	61	Unsprayed	15.6

* difference significant at the 5%, ** at the 1% level.
ns - not significant

DISCUSSION

Suckers compete with the parent tree for resources (Robinson, 1974) and can harbour diseases (Quinlan, 1976) therefore the control of suckering in combination with weed control in a single operation with one herbicide would be of practical value to growers. Glyphosate controls perennial weeds in orchards best when applied in the autumn and our results indicate that autumn spraying of glyphosate to fruit tree suckers can effectively kill suckers without damage to the parent tree. The results indicate no major redistribution of glyphosate between suckers (rootstocks) and tree (scion) and confirm the effects of winter, spring and summer applications on a range of fruit tree suckers reported by Atkinson (1977), Atkinson et al (1978) and Putnam (1976). However, our results also show that following autumn application some basipetal translocation and redistribution can occur within the rootstock itself. In the apple, pear and plum cultivars studied, new suckers which arose from the rootstock the following spring were fewer and shorter than in untreated trees and most showed signs of glyphosate damage (table 1).

During routine herbicide spraying there is the risk, especially in modern intensive orchards on dwarfing rootstocks, that spray will drift on to low branches. Stinchcombe and Stott (1978), showed that when conventional rates of glyphosate (2.4 kg a.e/ha) were applied in autumn to distal 20 cm of a lower branch of ornamental Malus pollinators widespread damage resulted in some cultivars the following spring. This suggested that the chemical could move downwards in the autumn from the sprayed zone (scion) into the tree trunk, roots and rootstock and upwards the following spring causing the widespread damage observed. In contrast in the present trial, autumn applications of glyphosate to a single branch of Cox's Orange Pippin apple, Victoria plum or Williams pear trees damaged the sprayed branch and not the remainder of the tree, similar to the general pattern of fruit tree response to spring and summer spraying of glyphosate reported by Putnam, 1976 and Stinchcombe and Stott, 1978. Yet with Kidd's Orange Red autumn application resulted in widespread damage to leaves and blossoms the following spring. These results indicate as with ornamental *Malus* pollinators the variable response of fruit tree cultivars to autumn applied glyphosate and the need for care when applying this herbicide.

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THE EFFECTS OF LATE SEASON APPLICATIONS OF GLYPHOSATE AND FOSAMINE TO FRUIT TREES WITH ROOT SUCKERS.

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Summary Root suckers of apple and plum trees were sprayed with glyphosate at 7.5 kg/ha a.e. on either 30 October or 8 November, pear suckers on 30 October and apple suckers with fosamine at 4.7 kg/ha a.i. on 30 October. Sprays caused no obvious damage to the apple or plum trees but parts of some pear trees showed typical glyphosate damage during the following spring. Sprayed suckers were killed or damaged depending upon the date of application. Kill by glyphosate varied from 34-81% of apple suckers and 35-43% for plums; both less than previously reported for summer applications. Fosamine killed 71% of apple suckers. Sucker regrowth was reduced by all sprays.

INTRODUCTION

Tree and shrub species are now becoming common weeds in established fruit plantations (Atkinson, 1980). These and other perennial weeds are both controlled by translocated herbicides, e.g. glyphosate or chemicals specifically active against woody species, e.g. fosamine. In established fruit plantations new shoots growing upwards from the root system (root suckers) are liable to be sprayed during herbicide application and so present a potential hazard if they translocate herbicides to the parent tree. However, previous studies showed that neither deliberate application of glyphosate to suckers nor simulated accidental sprays to suckers during the period February to July, appeared to cause damage to the parent tree (Atkinson, 1977; Atkinson et al., 1978b; Atkinson et al., 1978c). Applications of fosamine to pear trees, however, resulted in damage (Atkinson et al., 1978a). The above studies suggested that the absence of damage from glyphosate sprays to the suckers resulted from its strongly acropetal movement in growing shoots which resulted in its immobilization in dead sucker shoot tips. If this were the case then applications to non-dormant but non-growing shoots where the shoot tip would not act as a strong sink might be more likely to result in translocation and damage to the parent tree.

This paper describes the effects of sprays of glyphosate and fosamine applied to fruit tree suckers in the late autumn when they had ceased active shoot growth.

METHOD AND MATERIALS

Experiments were carried out in 1978 using trees of apple (28-year-old trees of Lanes Prince Albert on M.7) pear (12-year-old trees of Conference on Quince A) and plum (19-year-old of Victoria on St. Julien A). All trees were grown in either herbicide squares or strips with grassed alleys.

Herbicides were applied as described by Atkinson et al. (1978a,b). To maximize effects glyphosate was sprayed at 7.5 kg a.e./ha (approximately four times the recommended rate) so as to give complete cover of 1-year suckers. Sprays were applied on 30 October and 8 November to apple and plum trees and on 30 October to pear trees. Fosamine was applied at 4.7 kg a.i./ha to apple suckers only on 30 October. Treatments, including unsprayed controls were replicated six times (pear eight times) in a randomized block design.

Trees and suckers were examined in May 1979, at intervals during 1979 and again in May 1980. Damage to trees was recorded on a 1-5 scale (undamaged-dead). Effects on suckers were recorded as the number of dead 1978 suckers relative to the total number of suckers present (1978 + 1979). The mean numbers of suckers in 1979 were 54, 82 and 45 per tree of apple, pear and plum respectively.

RESULTS

Effects on the parent tree

None of the sprays applied to suckers caused any damage to either apple or plum trees. Treatments caused some damage (category 2 or 3) to a few branches on three of the eight treated pear trees. The damage was not detectable in 1980.

Effects on the suckers

In apple most suckers were killed by the October spray of glyphosate and a smaller number by the November spray (Table 1).

Table 1

The number of dead 1978 suckers as a percentage of the total number present in May 1979

	Treatment				
	Glyphosate		Fosamine	Unsprayed control	
	Date of spraying				
Species	30 Oct	8 Nov	30 Oct		SE
Apple	81	34	71	5	17
Pear	95	-	-	20	5
Plum	43	35	-	6	23

Treatment effects compared with unsprayed control were significant P = 0.05 by both Analysis of Variance and a Friedman non-parametric test.

Of those 1978 suckers not killed, most were damaged, i.e. showed typical symptoms of glyphosate damage; reduced lamina, inrolled leaf margins, etc. With the 8 November spray 48% of suckers were damaged so that the total numbers killed or damaged (82% in November, 98% in October) were similar. Suckers were in leaf on both dates. Fosamine also killed many apple suckers. Results for plum were similar to those for apple although fewer suckers were killed. The pear sucker control was almost complete.

For more permanent sucker control the treatment must affect both existing suckers and the emergence of new suckers either from treated suckers or from other points on the root system. In apple most new suckers arose from new positions on the root system (Tables 2 and 3). This seemed reduced by the October glyphosate spray but not by either the later spray or by fosamine. In pear and plum new suckers seemed to come mainly from existing suckers and their number was apparently reduced by glyphosate treatment.

Table 2

The number of new suckers arising from 1978 suckers, percentage of the total number of suckers present (living + dead)

	Treatment			
	Glyphosate		Fosamine	Unsprayed control
	Date of spraying			
Species	30 Oct	8 Nov	30 Oct	
Apple	0	0.2	0.2	4
Pear	0	-	-	8
Plum	2	25	-	57

Table 3

The number of new suckers coming directly from the soil surface, percentage of the total number present (living + dead)

	Treatment			
	Glyphosate		Fosamine	Unsprayed control
	Date of spraying			
Species	30 Oct	8 Nov	30 Oct	
Apple	1	9	8	13
Pear	1	-	-	0
Plum	0	0	-	1

DISCUSSION

If glyphosate is sprayed on individual branches of fruit trees it can cause severe damage to the sprayed branch and sometimes to other parts of the tree both in the year of spraying and subsequently (Davison, 1975). Previous studies have shown, however, that sprays to root suckers during the period February to July do not cause damage (Atkinson, 1977; Atkinson et al., 1978b,c). Atkinson et al. (1978b) suggested that the absence of translocation could have been due to the chemical, which seemed to move acropetally, becoming immobilized in the dead sucker shoot tip. Even when only the base of the sucker was sprayed damage was always most severe at the tip (Atkinson et al., 1978c). Thus, the mechanism of tolerance depends on the extent of translocation and immobilization in the sucker. The work reported here shows that late season applications, at a time when sucker growth had stopped, caused damage when earlier sprays did not (Atkinson et al., 1978b). Although damage was only visible in pear the effect on new sucker initiation suggested some basipetal movement in apple. This did not occur with fosamine which was shown by Atkinson et al. (1978a) to move during the growing period and cause damage in pears.

The effect of late season sprays on sucker mortality (34-81% in apple) was less than from sprays in June-July (95-100% in apple), (Atkinson et al., 1978b). The poorer control of plum suckers agrees with the results of Atkinson et al. (1978b). In contrast mortality resulting from fosamine sprays on apple was higher than that reported by Atkinson et al. (1978a).

These studies which involved a range of fruit crops indicated that late season applications of glyphosate to root suckers could, at least in pear, result in damage to the parent tree and should be avoided.

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3,6-DICHLOROPICOLINIC ACID FOR CONTROL OF CREEPING THISTLE (CIRSIUM ARVENSE) IN STRAWBERRIES

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Summary A programme of replicated trials carried out over a two year period has shown the potential of 3,6-dichloropicolinic acid for the control of Cirsium arvense in the U.K. strawberry crop.

A single application of 200 g a.e./ha to C. arvense at the 5-25 cm rosette stage gave good control in most cases. Where weed emergence occurred over a longer period, a sequential application of 100 + 200 g a.e./ha was somewhat more effective.

Applications of 200 g a.e./ha to strawberries, particularly at the pre-flowering stage, sometimes caused chlorosis and distortion of a proportion of new leaves. The balance between optimum timing for crop safety and for most effective weed control remains a subject for further investigation.

Résumé Un programme d'essais répétés pendant une période de deux ans, a indiqué le potentiel de l'acide 3,6-dichloropicolinique pour le contrôle de Cirsium arvense dans la culture des fraises en Grande-Bretagne.

Une simple application de 200 g a.e./ha sur C. arvense a l'état de rosette de 5 à 25 cm a donné un bon contrôle dans la plupart des cas. Quand des mauvaises herbes émergentes sont apparues pendant une longue période, une série d'applications de 100 + 200 g a.e./ha a été bien plus efficace.

Des applications de 200 g a.e./ha sur les fraises, particulièrement a l'état de la fleur, ont quelquefois causé chlorosis et une dénaturation d'un certain nombre de nouvelles feuilles. La balance entre le choix de meilleur moment pour la sécurité de la culture et pour le contrôle le plus efficace des mauvaises herbes reste un sujet de recherches ultérieures.

INTRODUCTION

3,6-dichloropicolinic acid was first developed, in mixture with other herbicides, for broad-leaved weed control in cereals (Haagsma, 1975; Brown and Uprichard, 1976; Gilchrist and Page, 1976 Mayes et al, 1976) and in oilseed rape (Rea et al, 1976). Its activity against perennial weed species such as Cirsium arvense was first reported by Keys (1975). Following reports of selectivity in sugar beet (Vernie et al, 1977), a formulation of 3,6-dichloropicolinic acid alone was developed in the United Kingdom for control of both broad-leaved weeds and Cirsium arvense in this crop (Gilchrist and Lake, 1978). Screening trials at the ARC Weed Research Organisation (Bailey and Clay, 1980) then indicated that this formulation of 3,6-dichloropicolinic acid also showed selectivity in strawberries, a crop in which C. arvense is a major problem in the United Kingdom, due to lack of suitable herbicides. Accordingly, a U.K. field trials programme was initiated in 1979 to evaluate the efficacy and safety of 3,6-dichloropicolinic acid, at various dose rates and timings, for the control of C. arvense in strawberries.

METHOD AND MATERIALS

The standard commercial formulation of 3,6-dichloropicolinic acid, containing 100 g a.e./litre, was used in all trials.

Two preliminary trials were carried out in 1979 to evaluate both control of C. arvense and crop safety. In 1980, two series of trials were carried out, the first (four trials) on sites infested with C. arvense, to evaluate various rates and sequences of 3,6-dichloropicolinic acid, primarily for weed control and secondarily crop safety. The second series (three trials) was carried out on weed-free sites, testing a wider range of timings and doses for crop safety. All trials were of randomised block design, with three replicates and a plot size of 15 m^2.

Sites were selected according to weed population, and covered most major fruit-growing areas of the U.K. A number of strawberry varieties were treated, and soil types ranged from coarse sandy loam to sandy clay loam. In some cases sites had received overall pre-emergence treatments (grower-applied) of standard strawberry herbicides such as lenacil.

Table 1

Site details

Year	Trial type	Location	Strawberry cultivar
1979	Preliminary	Wisbech, Cambs	Cambridge Favourite
1979	Preliminary	Scunthorpe, Humberside	Cambridge Favourite
1980	Efficacy	Melton Mowbray, Leics.	Cambridge Favourite
1980	Efficacy	Wisbech, Cambs	Cambridge Favourite
1980	Efficacy	Chipping Campden, Glos.	Cambridge Favourite
1980	Efficacy	Newmarket, Suffolk	Domanil
1980	Safety	Newmarket, Suffolk	Gorella
1980	Safety	Wisbech, Cambs.	Cambridge Favourite
1980	Safety	Wisbech, Cambs.	Totem

Experimental treatments were applied at one of three timings;

Early:	during first emergence of new leaves (mid April)
Pre-flowering:	new leaf growth established, many flower buds but few flowers (late April-early May)
Full flower:	majority of flowers open (late May)

All treatments were applied by Van der Weij propane sprayer using Delavan FJ 14 fanjets and a pressure of 2.0 bars to give a spray volume of 220 l/ha.

Control of Cirsium was assessed visually on a percentage basis, approximately one month after the final treatment at each site. Crop tolerance was also assessed visually 2-3 weeks and 5-8 weeks after each time of treatment. Crop yield at 1979 sites was determined by hand picking in July. Yields were not taken at 1980 efficacy sites, due to the effects of dense stands of Cirsium. Yields from 1980 safety trials are not available at the time of writing.

RESULTS

Table 2

Mean percent control of Cirsium arvense with 3,6-dichloropicolinic acid

Dose rate (g a.e./ha)			1979	1979	1980	1980	1980	1980	
Pre-flower*		Full flower*	Wisbech	Scunthorpe	Melton Mowbray	Wisbech	Chipping Campden	Newmarket	Mean
100		-	60	43	78	27	50	-	52
200		-	77	85	87	67	91	85	82
400		-	-	-	99	97	90	100	97
-		200	-	-	33	37	82	-	51
-		400	-	-	53	70	92	-	72
100	+	100	-	-	82	73	85	-	80
100	+	200	-	-	87	83	87	-	86
Control (% ground cover - June)			(65)	(60)	(85)	(80)	(70)	(15)	

* Cirsium growth stages - Pre-flower: 5-25 cm rosettes, occasional 5 cm shoots.

Full-flower: 15-30 cm rosettes, 15-45 cm shoots

Control of Cirsium arvense showed a clear response to both dose and timing of 3,6-dichloropicolinic acid. Applied pre-flower, 200 g a.e./ha gave generally good control, although less effective on occasional larger plants of Cirsium at sites where emergence occurred over a longer than average period. 400 g a.e./ha pre-flower gave control of even larger weeds. However, similar doses applied later, to *Cirsium* with developing flower shoots, proved much less effective, and even those plants which died remained as dried spikes for some time, presenting an obstacle to crop harvesting by hand pickers.

In crops such as sugar beet, two sequential applications of 3,6-dichloropicolinic acid were found necessary for adequate control of *Cirsium*, due to the extended period of emergence of this weed in arable fields (Gilchrist and Lake, 1978). In a perennial crop such as strawberries, the period of emergence of *Cirsium* appears shorter in many cases, and under these conditions, a sequential application of 100 + 200 g a.e./ha often showed no advantage over a single dose of 200 g a.e./ha applied pre-flowering.

Table 3

Mean percent visible crop damage at intervals after spraying

Dose rate (g a.e./ha)			1979 efficacy trials (2)		1980 efficacy trials (4)		1980 safety trials (3)	
Early	Pre-flower	Full flower	2 wks	5 wks	3 wks	6-8 wks	2-3 wks	5-6 wks
100	-	-	-	-	-	-	0.1	0
200	-	-	-	-	-	-	1.0	0.7
400	-	-	-	-	-	-	2.3	1.1
-	100	-	-	-	0.9	0.7	1.3	1.6
-	200	-	0	0	0.8	2.4	2.0	4.9
-	400	-	0.3	0	1.7	7.9	3.2	13.3
-	-	100	-	-	-	-	0.7	*
-	-	200	-	-	1.0	*	1.3	*
-	-	400	-	-	2.4	*	6.6	*
-	100	+ 100	-	-	0.4	*	-	-
-	100	+ 200	-	-	1.8	*	-	-
Control			0	0	0	0	0	0

* 5-6 wk assessment of full flower treatments not possible due to harvesting.

100 g a.e./ha of 3,6-dichloropicolinic acid caused only minimal crop effects at any time of application. 200 g a.e./ha caused slight chlorosis and leaf distortion of some new growth at certain sites. These effects increased somewhat with time, unlike sugar beet, where leaf effects from 3,6-dichloropicolinic acid are transient. Distortion consisted mainly of a narrowing of each leaflet, these becoming "strap-like" in extreme cases, with an overall leaf shape resembling a Maltese cross. Crop damage remained limited at the 200 g a.e./ha dose rate, but at 400 g a.e./ha became marked at some sites, particularly with later treatments.

100 g a.e./ha of 3,6-dichloropicolinic acid gave a small yield increase at 1979 sites (see Table 4) although this was not significant. 200 g a.e./ha, on the other hand, appeared to cause a yield decrease at one site, although again this was not significant.

Table 4

Mean yield of fruit as percent of untreated (1979)

Dose rate (g a.e./ha); pre-flower	1979 Wisbech	1979 Scunthorpe
Control	100	100
100	112	113
200	101	85
LSD 5%	NS	NS
Control Yield (t/ha)	4.1	3.0

DISCUSSION

At this stage in a continuing development programme, 3,6-dichloropicolinic acid shows considerable promise for control of the problem weed *Cirsium arvense* in strawberries. A single treatment of 200 g a.e./ha applied when *Cirsium* is in the rosette stage of growth, before extension of flowering shoots, gave satisfactory control in most cases. Sequential applications of 3,6-dichloropicolinic acid, as used in beet crops, offered little advantage unless *Cirsium* emerged over an extended period of time.

200 g a.e. of dichloropicolinic acid per ha appeared reasonably safe to the strawberry crop, but some chlorosis and distortion of new leaf growth may be caused.

Treatment during the immediate pre-flower period appears to cause more damage to the crop. As this stage of crop growth frequently coincides with the optimum growth stage for control of *Cirsium*, a conflict in timing arises, which will be further investigated in the coming season.

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Proceedings 1980 British Crop Protection Conference - Weeds

THE SAFETY AND EFFECTIVENESS OF 3,6-DICHLOROPICOLINIC ACID FOR THE CONTROL OF CIRSIUM ARVENSE IN STRAWBERRIES

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Summary In pot experiments, strawberries, cv. Cambridge Favourite, were relatively tolerant of 3,6-dichloropicolinic acid applied to shoots or roots at 0.2 kg/ha, the dose normally required for control of *Cirsium arvense*. At this dose both methods of application led to the development of a few distorted leaves but subsequent growth was normal. When the response of five cultivars was compared, Cambridge Favourite was the least tolerant and Cambridge Vigour and Gorella the most tolerant. Application to foliage during flowering affected petal shape and colour and caused bending of peduncles. Fruit ripening of some cultivars was advanced but total fruit yield was unaffected. Addition of lenacil (1.5 kg/ha) or phenmedipham (0.8 kg/ha) did not generally increase damage.

In field experiments application of 0.2 and 0.4 kg/ha to *C. arvense* in established strawberries in early June or August killed weed shoots and also greatly reduced weed growth the following spring. 2,4-D amine (2.5 kg/ha) in August was much less effective.

The results show the value of the treatment on dense *C. arvense* infestations. Problems relating to the timing of the treatment to give weed free conditions at fruit harvest and acceptable crop tolerance are discussed.

INTRODUCTION

Cirsium arvense has probably been the biggest perennial broad-leaved weed problem in strawberries in the U.K. in recent years. It is widespread both in traditional strawberry-growing areas and elsewhere on plantations established on former arable or pasture land. Crop yields are reduced, not only by weed competition but also by the prickles deterring pickers. Control by hand-pulling is expensive and short-lived. The only herbicides used, 2,4-D and glyphosate are often unsatisfactory. 2,4-D amine applied in late spring to newly-planted crops or post-harvest on established crops kills the weed foliage but there is generally some regrowth before the next harvest (Davison & Bailey, 1978). Glyphosate, used as a spot treatment, is more effective but can be very toxic to the crop.

Haagsma (1975), Brown & Uprichard (1976), and Richardson & Parker (1976, 1977) reported the activity of 3,6-dichloropicolinic acid against Compositae weeds including *C. arvense*. While activity on many weeds was enhanced by mixture with other herbicides it was effective on its own against *C. arvense* in U.K. conditions (Gilchrist & Lake, 1978). In 1979 the herbicide was recommended for use in sugar beet either alone or mixed with lenacil and/or phenmedipham to broaden the weed control spectrum (Farm Protection, 1979).

Pot tests on the tolerance of strawberries to 3,6-dichloropicolinic acid applied to foliage or roots were carried out at WRO in 1978. In 1980 the tolerance of commonly-grown cultivars was compared. Field trials on the effectiveness of the herbicide on C. arvense in established strawberries were carried out in 1979/80. The results of this work are reported in this paper.

METHOD AND MATERIALS

Herbicides were applied to the strawberries at the doses, dates and conditions shown in Table 1. The herbicide formulations were:- 3,6-dichloropicolinic acid, 10% a.e., a.c., lenacil, 80% w.p., phenmedipham, 11.4% e.c. and 2,4-D amine, 32% a.e.

Table 1

Application details for treatments with 3,6-dichloropicolinic acid (D), lenacil (L), phenmedipham (P) and 2,4-D

Experiment	Herbicide Herbicide	Dose (kg/ha)	Spray volume (l/ha)	Jet size (Tee jet)	Spraying pressure (bars)	Treatment dates
1	D	0.05,0.2,0.8	394	8002E	2.1	7.6.78
	P	1.1,2.2,4.4	240	80015E	2.1	"
2	D	0.8‡,3.2,12.8, 51.2,204.8	-	-	-	13.7.78
3,4	D	0.1,0.2,0.4,0.8	234	80015E	2.1	16.5.80
4	D* + L	1.5	"	"	"	"
4	D* + P	0.8	"	"	"	"
5,6	D	0.2,0.4	200	8002	2.0	(1.6.79
	2,4-Dø	2.5	"	"	"	(28.8.79

*D at the four doses shown above ø post-harvest only, Expt 5 ‡ doses as mg/pot

Experiment 1 Tolerance to foliar application. The test of foliar activity was carried out using the method described by Clay (1980a). Strawberry runners, cv. Cambridge Favourite, were planted in a peat-based compost in 18 cm diameter pots on 8.5.78 and grown outdoors. The 3,6-dichloropicolinic acid treatments were part of a large herbicide screening experiment in which phenmedipham was included as a standard safe treatment; there were four replicates of each treatment. Plants were sprayed with a laboratory pot sprayer when they had 3-5 new leaves. Herbicide was kept off the compost during spraying and the plants were grown on outdoors using a mobile transparent cover to keep rain off. The compost surface was watered as necessary avoiding the foliage. Stolons were removed at intervals. Plant vigour was assessed visually at intervals after spraying using a 0-9 scoring scale (0 = plant dead, 5 = 50% growth inhibition, 9 = plant normal). Leaves were cut and weighed on 31.7.78; the plants were grown on and leaf fresh weight recorded on 4.12.78.

Experiment 2 Tolerance to root applications. The test of activity of the herbicide applied to the roots of plants growing in sand culture was carried out using methods described by Clay (1980a). Strawberry runners, cv. C. Favourite, were planted in silica sand in 25 cm diam. pots on 4.5.78 and grown on outdoors. The experiment was laid out as randomised blocks with three replicates. Pots standing in foil dishes were treated by applying the herbicide to the sand surface in 500 ml nutrient solution. Subsequently nutrient solution was added to the sand surface as necessary but rain was kept off the pots during the experiment. Assessments were carried out as in Experiment 1.

Experiment 3 Tolerance of different cultivars. Runners of five commonly grown cultivars (listed in Table 4) were planted on 25.10.79 in sandy loam soil in 18 cm diameter pots with added fertilizer and grown on outdoors. 3,6-dichloropicolinic acid was applied on 16.5.80 using a laboratory pot sprayer. There were six replicates of each treatment. Spray was not kept off the soil surface. At the time of spraying all plants were growing vigorously, flowering, and some fruit was forming. After spraying plants were grown on outdoors (without rain protection), laid out as randomised blocks. There was no rain for 3 days after spraying. All pots were watered lightly overhead 2 days after spraying and subsequently as necessary. Assessments were made during the experiment as shown in Table 4.

Experiment 4 Tolerance to herbicide mixtures. The tolerance of cv. Cambridge Vigour to mixtures of 3,6-dichloropicolinic acid with phenmedipham or lenacil was tested on plants grown in the same conditions and treated and assessed at the same time as Experiment 3.

Experiment 5 C. arvense control - Hinckley. Plots measuring 6 x 3 m were laid out on an area of strawberries cv. Cambridge Favourite planted in autumn 1977 which was infested with C. arvense. Plots were allocated to the six blocks according to the density of weed. A pressurized knapsack sprayer was used for spraying. At the first application date there was a maximum of 60 C. arvense shoots/m^2 up to 30 cm high with the majority at 20 cm. C. arvense shoots on the control plots and those to be treated with 2,4-D were pulled before fruit harvest; at the time of post-harvest spraying weed shoots on these plots were up to 20 cm high. The % ground cover of C. arvense was assessed on 20.4.80 and the number of shoots/plot counted on 16.5.80.

Experiment 6 C. arvense control - Southam. Plots were laid out on an area of strawberries cv. C. Favourite planted in 1977. Dimensions, layout, weed density and growth stage, spraying details and assessments were the same as in Experiment 5. Weeds on control treatments were hand-pulled in late June. No post-harvest treatments were applied but the whole area received a commercial application of 2,4-D amine at 1 kg/ha a.e. on 20.8.78. At this time, C. arvense shoots on control plots were up to 20 cm high.

RESULTS

Experiment 1 Tolerance to foliar application. All doses of 3,6-dichloropicolinic acid caused some thickening and stunting of younger sprayed leaves within 1 week of treatment. At the two higher doses new leaves growing out after spraying showed severe distortion; leaflets were short and narrow due to absence of mesophyll development. At 0.2 kg/ha two or three distorted leaves were produced before normal leaf growth was resumed (Table 2). At this dose the first leaf on each runner that developed in the month after spraying was distorted but subsequent leaves were normal. More leaves were affected on runners from plants treated with 0.8 kg/ha but neither treatment reduced number or weight of runners in the 2 months after treatment. Leaf fresh weight measured two months after treatment was not affected and subsequent growth of all treatments was normal (Table 2).

Phenmedipham, at the rate recommended for strawberries (1.1 kg/ha) caused marginal chlorosis of younger sprayed leaves but no effect on long-term growth (Table 2). The higher doses caused chlorosis and necrosis of sprayed leaves but the effect was outgrown by the end of the experiment.

Experiment 2 Tolerance to root applications. Except for the lowest dose all treatments caused severe leaf epinasty and inrolling of young leaflets within 1 week of application (Table 3). Leaves developing after treatment at all doses showed distortion but this was restricted to one or two leaves per plant with the lowest dose, and subsequent leaves were normal. Leaves developing on runners showed similar distortion except at the lowest dose. With the three highest doses most plants subsequently died in the autumn but plants treated with the lower doses recovered completely. These were grown on the next year to flowering and fruiting and no abnormalities were observed.

Table 2

The effect of 3,6-dichloropicolinic acid and phenmedipham applied to the foliage of strawberries cv. C. Favourite (Experiment 1)

Herbicide	Dose (kg/ha)	Vigour score (% untreated) 6.7.78	Vigour score (% untreated) 31.7.78	Leaf fresh wt (% untreated) 1.8.78	Leaf fresh wt (% untreated) 4.12.78
3,6-dichloro-picolinic acid	0.05	89	103	106	104
	0.2	67	87	108	99
	0.8	47	67	95	105
phenmedipham	1.1	80	90	101	108
	2.2	72	80	95	93
	4.4	63	74	82	104
untreated control (actual values)		100 (9.0)+	100 (7.7)+	100 (65.9 g/plant)	100 (28.7 g/plant)
SE ±		2.2	5.5	4.4	7.7

+actual values for scores on 0-9 scale

Table 3

The effect of 3,6-dichloropicolinic acid applied to the roots of strawberries cv. C. Favourite growing in sand culture on 13.7.78 (Experiment 2)

Herbicide	Dose (mg/pot)	Vigour score (% untreated) 28.7.78	18.8.78	7.9.78	Leaf fresh wt (% untreated) 11.9.78	19.12.78
3,6-dichloro-picolinic acid	0.8	84	82	80	105	110
	3.2	43	44	43	81	98
	12.8	38	35	27	74	7
	51.2	27	32	23	46	0
	104.8	27	24	11	20	0
untreated control (actual values)		100 (8.7)+	100 (8.5)	100 (8.7)	100 (132 g/plant)	100 (24.8 g/plant)
SE ±		3.8	3.9	3.9	5.7	6.3

+Vigour score, 0-9 scale

Experiment 3 Tolerance of different cultivars. The first treatment effects seen were on the flower/fruit trusses. Petals developing after spraying were redder in colour, narrower, often reflexed and with wavy margins. At doses of 0.2 kg/ha and above peduncles were twisted and, with C. Favourite and Gorella, elongated. Fruit was removed when the first berries were ripe. With C. Vigour and Gorella the amount of ripe fruit was significantly increased by the herbicide (P = 0.05) (Table 4). There was no significant reduction in the total amount of fruit/plant for any cultivar (P = 0.05). There were clear differences between cultivars in severity of leaf distortion on leaves developing after spraying; C. Favourite was the cultivar most affected and Gorella and C. Vigour the least. There were no distorted leaves formed with 0.1 kg/ha on C. Vigour. At the 0.4 and 0.8 kg/ha doses no normal leaves were produced on C. Favourite in the 2 months after treatment whereas other cultivars recovered. At the end of the experiment the doses causing a significant reduction (P = 0.05) in leaf weight were 0.4 kg/ha on C. Favourite and 0.8 kg/ha on the other cultivars.

Experiment 4 Tolerance to herbicide mixtures. The addition of lenacil (1.5 kg/ha) had no effect on the response of the crop to increasing doses of 3,6-dichloro-

Table 4

The effect of 3,6-dichloropicolinic acid applied on 16.5.80 on the strawberry cultivars Cambridge Favourite (F), Redgauntlet (R), Montrose (M), Gorella (G) and Cambridge Vigour (V). Experiment 3

Dose (kg/ha)	Vigour score 20.6.80 (% untreated)					Fresh wt ripe fruit 17.6.80 (g/plant as log (x+1))				No. of distorted leaves/plant 7.7.80 (% total leaf no. on untreated)				
	F	R	M	G	V	F	R	G	V	F	R	M	G	V
0.1	74	81	81	92	84	0	0	0.90	1.20	27	24	11	2	0
0.2	62	60	62	77	76	0	0	0.69	1.12	41	30	30	16	15
0.4	44	46	50	54	48	0.20	0.20	0.23	1.39	46	37	41	26	34
0.8	38	37	42	42	46	0	0	0.82	1.16	58	45	43	41	38
untreated (actual value)	100 (8.3)[ø]	100 (8.3)	100 (8.0)	100 (8.0)	100 (8.0)	0	0	0.22	0.42	0 (4)[+]	0 (13)	0 (20)	0 (14)	0 (17)
SE ±			2.5%				0.178					4.5%		

Dose (kg/ha)	Normal new leaves 17.7.80[•] number/plant					Leaves, fresh wt/plant 18.7.80 (% untreated)					Vigour score, 17.7.80 (% untreated)				
	F	R	M	G	V	F	R	M	G	V	F	R	M	G	V
0.1	3	4	4	-[‡]	-[‡]	91	97	104	93	87	72	79	76	98	96
0.2	2	2	3	5	5	88	96	102	100	87	57	62	61	76	73
0.4	0	2	2	4	4	64	83	84	102	88	40	51	50	62	62
0.8	0	1	0	1	3	55	71	61	79	79	33	44	40	48	56
untreated (actual value/plant)	-	-	-	-	-	100 (47.4)	100 (39.6)	100 (42.6)	100 (46.4)	100 (41.7)	100 (9.0)[ø]	100 (9.0)	100 (9.0)	100 (9.0)	100 (9.0)
SE ±								5.8%					1.8%		

[+] Plant leaf number

[ø] Vigour score, 0-9 scale

[‡] No distorted leaves formed

[•] Number of normal leaves produced after distorted leaves picolinic acid (Table 5). Slight veinal chlorosis was observed on one or two leaves per plant present at spraying but there was no effect on fruiting, severity of leaf distortion or recovery from it. The mixture with phenmedipham caused some marginal chlorosis and necrosis of younger leaves present at spraying but development of subsequent leaves was the same as with 3,6-dichloropicolinic acid alone (Table 5).

Table 5

The effect of mixtures of 3,6-dichloropicolinic acid (D) with lenacil (L) and phenmedipham (P) on strawberries cv. Cambridge Vigour (Experiment 4)

Herbicide and dose	Vigour score (% untreated)			Distorted leaves[ø]	Normal new leaves[●]	Leaf fresh wt (% untreated)
	28.5.80	20.6.80	17.7.80	7.7.80	17.7.80	18.7.80
D 0.1	78	87	95	0	-[‡]	87
D 0.1 + L 1.5	78	90	91	4	-	116
D 0.1 + P 0.8	67	84	92	2	-	97
D 0.2	67	79	73	15	5	87
D 0.2 + L 1.5	69	77	75	17	5	107
D 0.2 + P 0.8	52	75	75	13	5	90
D 0.4	59	50	62	34	4	87
D 0.4 + L 1.5	63	62	69	35	4	105
D 0.4 + P 0.8	48	54	61	39	4	92
D 0.8	53	47	55	38	3	79
D 0.8 + L 1.5	55	46	53	37	2	87
D 0.8 + P 0.8	47	47	50	39	3	79
Untreated control	100	100	100	0	-[‡]	100
(actual value)	(9.0)[+]	(8.0)[+]	(9.0)[+]	(17/plant)		(41.7 g/plant)
SE ±	2.0%	2.3%	3.0%	3.6%	-	6.3%

[+] Vigour score, 0-9 scale

[‡] No distorted leaves on most plants

[ø] Number of distorted leaves as % leaf no. on untreated

[●] Number of normal leaves/plant produced after distorted leaves

Experiments 5 and 6 Cirsium arvense control. In Experiment 5 the treatments at the beginning of June killed off the tops of weed shoots by fruit harvest but left stem bases and dead leaves amongst the crop. The post-harvest treatments also killed off sprayed shoots. There was little regrowth of C. arvense in the following spring on treatments receiving 0.4 kg/ha 3,6-dichloropicolinic acid at either date. At the lower dose regrowth on most plots was likewise small but extensive weed growth on one replicate in each treatment led to relatively higher mean values. The post-harvest 2,4-D treatment was less effective, only giving a 23% reduction in regrowth in spring compared with the control (Table 6).

In Experiment 6 early June treatments with the herbicide gave almost complete control of C. arvense in the following spring (Table 6). In both experiments 3,6-dichloropicolinic treatments caused slight epinasty of strawberry leaves after spraying, a few leaves subsequently showing distortion but no long-term adverse effects were observed.

DISCUSSION

Strawberries were tolerant to foliar applications of 3,6-dichloropicolinic acid at doses likely to be required for effective weed control (0.05-0.2 kg/ha) though a few distorted leaves were produced on each plant at the higher rate (see Clay (1980b) for an illustration of damage symptoms). A similar result was found with applications

Table 6

The effect of 3,6-dichloropicolinic acid and 2,4-D on Cirsium arvense in strawberries (Experiment 5 (Hinckley) and 6 (Southam))

Herbicide	Dose and time[+] (kg/ha)	HINCKLEY % ground cover 25.4.80 % untreated	HINCKLEY Shoot numbers 16.5.80 (% untreated)	SOUTHAM Shoot numbers 16.5.80 (% untreated)
3,6-dichloropicolinic acid	0.2 F	19	24	5
	0.4 F	4	4	2
	0.2 F + 0.2 PH	25	16	-
	0.2 F + 0.4 PH	7	3	-
2,4-D	2.5 PH	63	77	-
Untreated control (actual values)		100 (15%)	100 ($28/m^2$)	100 ($25/m^2$)
SE ±		17.0	12.0	0.9

[+] Application timing, F = strawberry flowering, 1.6.79; PH = post-harvest 28.8.79

to the roots in sand culture. At the lowest dose tested in sand a few distorted leaves developed but the effect was quickly outgrown and plants also recovered from the higher dose. The lowest dose (0.8 mg/pot) is roughly equivalent to an application of 0.2 kg/ha to the surface. The results suggest that, in the field, even if heavy rain leached the herbicide into the root zone there may be no long-term damage. In the field, the herbicide can be leached into the root zone (Brown & Uprichard, 1976) but the amount reaching the roots should be less than in the sand culture system assuming deeper rooting and some herbicide adsorption and breakdown in soil (Richardson & Parker, 1976).

Results from the field trials reported here and experience elsewhere has confirmed these preliminary findings (Lake & Bennett, 1980; H.M. Lawson, personal communication). While applications at 0.2 kg/ha lead to the production of a few distorted leaves on each plant there appeared to be no long-term effect on growth. Applications in spring may sometimes depress yield slightly and bigger yield depressions have been caused by 0.4 kg/ha (H.M. Lawson, 1980, personal communication), but the adverse effects are probably small compared with the serious crop losses if *C. arvense* is not controlled. Most of the field experience has been with cv. C. Favourite. In the varietal tolerance trial this appeared to be more susceptible than other commonly-grown cultivars, so in practice less leaf damage may occur with these, particularly Gorella and C. Vigour. Since both lenacil and phenmedipham are recommended in strawberries mixtures with 3,6-dichloropicolinic acid could be useful. In Experiment 4, addition of lenacil (1.5 kg/ha) had no adverse effect. The damage caused by the phenmedipham in the mixture (chlorosis and necrosis) was no greater than that caused by the same dose of phenmedipham alone sprayed on identical plants a few days earlier, both applications being made in hot weather. Further work is needed to establish the safety of these mixtures.

The *C. arvense* control obtained by treatment with 3,6-dichloropicolinic acid during crop flowering and post-harvest was good although there was sometimes more regrowth the following year with the 0.2 kg/ha treatment. (In Experiment 6, the 2,4-D applied to the treated plots post-harvest is unlikely to have affected regrowth since there was little weed present on these plots in August.) Good results were also obtained by Lake & Bennett (1980) with pre-flowering and post-flowering treatments with 3,6-dichloropicolinic acid though some regrowth occurred from 0.2 kg/ha doses. While 3,6-dichloropicolinic acid treatment is clearly a big improvement on any previous method of *C. arvense* control in strawberries further information is needed to establish the best dose and timing. The herbicide is generally less effective on large C. arvense and post-flowering applications in strawberries can leave dead shoots and living stem bases that will deter pickers. Treatment during flowering can affect flower morphology and may have unacceptable effects on fruiting. In the varietal tolerance test, however, treatment during flowering hastened ripening of some cultivars. Pre-flowering treatments may be unsatisfactory by permitting further C. arvense shoots to emerge before harvest. Sequential treatments in spring involving a lower dose have been effective in an arable situation (Gilchrist & Lake, 1978) where C. arvense is growing in cultivated soil in a competitive crop, but higher doses may be needed on the weed in undisturbed soil. Lake & Bennett (1980) found no benefit from sequential treatments in established strawberries. The possibility that post-harvest treatment will delay weed shoot emergence the next spring until flowering of the crop has commenced has been suggested but this did not occur in Experiment 5 (Table 6), so early re-treatment of areas sprayed the previous summer may be possible.

The crop tolerance data available so far indicates that the treatment is relatively safe, therefore overall or spot applications are clearly advantageous in serious C. arvense infestations. However, the possibility that crop yields can be depressed by spring treatments suggests that overall applications in spring for control of light infestations of C. arvense or other weeds may not be advisable. There is a need for further information on the effect of treatments on yield, including the effects of spraying during flowering, so that the safest and most effective use can be made of this very promising herbicide treatment.

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THE RESPONSE OF STRAWBERRIES TO SPRING APPLICATIONS OF PENDIMETHALIN

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Summary Pendimethalin at 2 and 4 kg/ha was applied to strawberry cv. Cambridge Favourite at 16 sites on three dates in the spring. Leaf checking occurred, especially with late applications of the high dose. At most sites there was complete recovery and no effect on yield. At some sites where leaf checking was severe total yield or mean fruit weight was reduced. It is concluded that pendimethalin is safe for use in strawberries.

INTRODUCTION

Pendimethalin is marketed in the UK for the control of Alopecurus myosuroides (black-grass) in winter barley. It has been shown to be potentially safe in strawberries in sand culture tests at WRO (Clay and Davison, 1978). Field experiments at the Weed Research Organization, the Scottish Horticultural Research Institute and the Horticultural Centre, Loughgall confirmed it to be a potentially safe treatment in both newly-planted and fruiting crops (Clay et al., 1974; Loughgall, 1977, Clay, 1978; Lawson and Wiseman, 1978). It was noted that leaf growth was checked but there was no adverse effect on yield and sometimes there was an increase in either total yield or early yield.

Pendimethalin has advantages over lenacil, which is widely used on fruiting crops in the spring. It controls a number of lenacil-resistant weeds such as Euphorbia helioscopia (sun spurge), Galium aparine (cleavers), Viola arvensis (field pansy), Lamium amplexicaule (henbit dead-nettle), Lamium purpureum (red dead-nettle) and Veronica spp. (speedwells); it is active under dry conditions (Clay et al., 1974). Senecio vulgaris (groundsel) is tolerant to pendimethalin but this can be controlled by the addition of propachlor (Clay, 1978).

However, more information has been needed on the effect of pendimethalin on fruit yield. Results are presented from a series of experiments in which pendimethalin at 2 and 4 kg/ha was applied to commercial crops of strawberry on three dates in the spring.

METHOD AND MATERIALS

Sixteen experiments were carried out in commercial crops of strawberry cv. Cambridge Favourite grown as matted rows. Location, soil type, planting and treatment dates and number of replicates are given in Table 1.

Pendimethalin, 33% e.c., was applied at 2 kg/ha on three dates at each site except Wokingham where it was applied at two dates. At one of the dates at each site, pendimethalin was also applied at 4 kg/ha. At three sites, Evesham, Stratford and Chipping Campden, propachlor (65% w.p.) at 4.5 kg/ha was added to the pendimethalin. Lenacil (80% w.p.) at 2 kg/ha was applied in February as a safe standard at all except three sites. At Evesham lenacil was applied at 1 kg/ha and at Wisbech and Outwell the standard was chloroxuron (50% w.p.) at 4.5 kg/ha. There was an unsprayed area of 1 x 0.9 m in each control plot; the remainder of the plot being sprayed with lenacil in March.

Table 1

Site details

Site	Location	Soil type	Planting date	Treatment date (1980)			Replication	No. of times fruit picked
				Feb	Mar	Apr		
1	Chelmsford	SL	Spring '79	18	12	8	6	2
2	Billericay	CL	" "	18	12	8	4	2
3	Upminster	CL	" "	18	12	8	5	1
4	Stow	SCL	August '77	20	14	9	4	2
5	Evesham	LS		20	14	9	5	2
6	Worcester	ZL	November '78	20	14	9	4	2
7	Alcester	SL	October '78	19	13	9	5	2
8	Stratford	CL	Autumn '78	19	13	9	4	3
9	C. Campden	SCL	October '78	19	13	9	4	3
10	Woodstock	ZCL	Autumn '78	21	20	11	4	4
11	Oxford	SCL	OOctober '78	21	20	11	4	5
12	Thame	SCL	Spring '77	21	20	11	4	4
13	Wokingham	SL	September '78	22	20	-	4	1
14	Wisbech	ZL	Autumn '77	25	21	10	4	2
15	Outwell	ZL	November '78	25	21	10	4	1
16	Swaffham	SL	Autumn '78	25	21	10	4	1

S Sand, L Loam, C Clay, Z Silt

Plots were 5 m long and 1 row wide (0.9 m). They were arranged in randomised blocks. Treatments were applied with a CO_2 pressurised knapsack sprayer in 330 l/ha at 2 bar using three Teejet 6502 fan nozzles held 30 cm above the crop to give a swath of 0.9 m.

Assessments were confined to the centre 4 m of the plots. The percentage of the ground covered by the crop and the number of crowns per plot were assessed at the outset. Leaf growth was assessed in May and early June on a scale of 0-9 (0 = dead, 3 = very stunted, still growing, 5 = 50% growth reduction, 7 = readily distinguishable growth reduction and 9 = undistinguishable from lenacil-treated controls). At five sites the height of the leaf canopy was measured in May at ten points at 30 cm intervals along the plots.

The effect on cropping was assessed as the fruit matured. At two sites the fruit was picked to commercial standards for the dessert market. Fruit was picked four times at Thame and five times at Oxford. On each occasion ripe fruit was counted and weighed. Diseased fruit was also removed and weighed. At the remaining 14 sites fruit was picked from 1 to 4 times. On each occasion the coloured fruit was removed, counted and weighed. Diseased fruit was removed and weighed. At the final pick the remaining green fruit was removed on the trusses and weighed.

There were insufficient weeds on the untreated part of the control plots to permit a weed assessment.

RESULTS

Scores for crop vigour in early May (Table 2) show that at nearly all sites pendimethalin had a significant effect. Typical symptoms were leaf stunting due to shortening of the petioles and leaflets becoming convex; some slight yellowing also occurred. Response was greatest with the later application and at 7 of the 11 sites where 4 kg/ha was applied in March or April it had a significantly greater effect than 2 kg/ha. At the five sites where height of the leaf canopy was measured, scores of 6 and 7 corresponded with a decrease in height of 27 to 18% and scores of 8 or slightly below with a reduction of 11 to 17%. The low scores at Billericay were the result of Red Spider Mite (Tetranychus urticae) and the crop at Wokingham was not assessed because it was affected by aphids (Chaetosiphon fragaefolii). Scores for crop vigour in early June at seven of the sites, i.e. approximately four weeks after the first assessment, showed that the plants were recovering. Only seven treatments out of 28 were still significantly reducing crop vigour compared with 16 at the earlier date.

Total yields of fruit are presented in Table 3. There were significant reductions with two of the 47 applications of 2 kg/ha and with two of the 16 applications of 4 kg/ha. An average of the results from all sites shows that pendimethalin at 2 kg/ha reduced yields by less than 5% and only 9% where 4 kg/ha had been applied in April at four sites.

Yields of coloured fruits harvested are presented in Table 4. There was no effect on the rate of ripening or the proportion of fruit made unsaleable by disease at Oxford and Thame, the two sites that were harvested commercially. Similarly, pendimethalin had no statistically significant effect ($P = 0.05$) on the weight of coloured fruit harvested from the 41 applications of 2 kg/ha or the 14 applications of 4 kg/ha at the remaining 14 sites. At individual sites there were non-significant increases of up to 21% and reductions of 18%; the average of all sites show that pendimethalin affected the weight by a maximum of 6%.

Average weight of coloured fruit is presented in Table 5. The April applications of pendimethalin at 2 and 4 kg/ha at the Stratford site were the only ones causing a significant reduction in mean fruit weight.

DISCUSSION

1980 was a year of extremes of weather. New leaves were unfolding on the strawberry plants when the first treatments were applied in mid-February and the plants showed little change when the last treatments were applied two months later. The soil surface was dry at some sites for the first application but the soil beneath was wet. The soil surface was wet at most sites for the second application and even where it was dry there had been rain since the first application. The soil surface was dry at all sites for the third application and it continued dry until 7 June. From then until harvest time there was more than average rainfall at all sites, and most crops were more leafy than usual; up to 40% of the fruit was affected by grey mould (Botrytis cinerea).

The reductions in leaf growth caused by pendimethalin are consistent with those reported earlier (Clay, 1978). Dose and timing of application were more important in determining the level of symptoms than soil type. Recovery was complete at most sites but plots that were scored 6 or less in early May were still stunted at harvest.

Pendimethalin had very little effect on the total weight of fruit produced, the speed of ripening or mean fruit weight. The few reductions that are statistically significant are mainly confined to late applications and high doses, which also caused an appreciable leaf response. At other sites comparable reductions in leaf growth did not reduce yield. The addition of propachlor at three sites does not

Table 2

Scores for crop vigour

Scored 0-9: 0 = plants dead, 5 = 50% growth inhibition, 9 = undistinguishable from control

Location	Control*	Lenacil^ø 2 kg/ha February	Pendimethalin 2 kg/ha			Pendimethalin 4 kg/ha			S.E. ±	LSD (p = 0.05)
			Feb	Mar	Apr	Feb	Mar	Apr		
Chelmsford	9.0	9.0	9.0	8.0	6.5	x	x	5.0	0.24	0.73
Billericay	4.0	3.8	4.3	4.3	4.3	x	3.8	x	0.76	NS
Upminster	9.0	9.0	9.0	9.0	7.0	9.0	x	x		
Stow	8.8	8.8	9.0	7.8	6.5	8.5	x	x	0.22	0.65
Evesham	9.0	8.8	8.3	8.5	6.3	x	7.5	x	0.28	0.85
Worcester	9.0	9.0	9.0	8.0	5.8	x	x	4.3	0.23	0.69
Alcester	9.0	8.3	8.8	7.3	6.8	x	7.3	x	0.23	0.71
Stratford	8.8	9.0	8.0	8.0	5.5	x	x	4.0	0.25	0.60
C. Campden	9.0	9.0	8.8	7.8	6.8	8.3	x	x	0.26	0.80
Woodstock	8.8	9.0	9.0	8.0	6.8	x	7.8	x	0.17	0.52
Oxford	8.8	9.0	8.8	8.0	6.5	x	6.3	x	0.22	0.65
Thame	9.0	8.8	8.8	7.8	5.0	x	7.0	x	0.23	0.69
Wokingham	-	-	-	-	x	x	-	x		
Wisbech	8.8	9.0	8.3	7.3	5.0	x	5.3	x	0.24	0.75
Outwell	9.0	9.0	8.0	7.8	6.8	x	x	4.3	0.17	0.52
Swaffham	9.0	9.0	8.5	7.0	5.5	7.8	x	x	0.31	0.95
Mean of all sites	8.6	8.6	8.4	7.6	6.1	8.4	6.4	4.4		

* Lenacil @ 2 kg/ha applied in March

ø except Evesham - lenacil 1 kg/ha; Wisbech and Outwell - chloroxuron 4.5 kg/ha

x no treatment

\- not assessed

Table 3

The total weight of fruit harvested (as % of control)

Location	Control* (g/m row)	Lenacil ø 2 kg/ha	Pendimethalin 2 kg/ha			Pendimethalin 4 kg/ha			S.E. ± %	LSD (p = 0.05)
			Feb	Mar	Apr	Feb	Mar	Apr		
Chelmsford	1229	90	109	87	94	x	x	99	6.6	NS
Billericay	843	91	107	108	98	x	91	x	13.2	NS
Upminster	819	95	102	88	82	96	x	x	12.0	NS
Stow	2179	98	101	83	93	87	x	x	6.8	NS
Evesham	1134	103	101	95	90	x	110	x	11.8	NS
Worcester	1849	113	106	89	89	x	x	77	7.5	23.4
Alcester	603	87	100	108	97	x	99	x	5.1	NS
Stratford	1654	110	100	104	104	x	x	93	9.3	NS
C. Campden	1020	99	109	117	105	119	x	x	7.5	NS
Woodstock	1731	106	100	106	106	x	97	x	6.4	NS
Oxford	3440	104	93	95	101	x	91	x	2.2	6.8
Thame	1864	101	112	100	93	x	90	x	4.8	14.9
Wokingham	648	141	126	93	x	x	109	x	10.7	33.1
Wisbech	2292	106	99	92	88	x	88	x	2.6	8.1
Outwell	1337	103	91	97	96	x	x	94	5.5	NS
Swaffham	832	99	110	99	106	106	x	x	4.6	NS
Mean of all sites		106	104	98	97	104	97	88		

* Lenacil @ 2 kg/ha applied in March
ø except Evesham - lenacil 1 kg/ha; Wisbech and Outwell - Chloroxuron 4.5 kg/ha
x no treatment

Table 4

Total weight of coloured fruit harvested (as % of control)

Location	% total picked	Control* (g/m row)	Lenacil[ø] 2 kg/ha	Pendimethalin 2 kg/ha			Pendimethalin 4 kg/ha			S.E.. ± %	LSD (p = 0.05)
				Feb	Mar	Apr	Feb	Mar	Apr		
Chelmsford	44	546	88	113	92	101	x	x	97	7.7	NS
Billericay	54	455	82	100	91	90	x	87	x	9.7	NS
Upminster	47	382	95	100	95	82	105	x	x	12.5	NS
Stow	62	1353	102	118	92	114	91	x	x	8.7	NS
Evesham	60	683	110	103	102	101	x	112	x	12.7	NS
Worcester	44	818	127	103	99	98	x	x	91	6.3	19.5
Alcester	-	-	-	-	-	-	-	-	-		
Stratford	84	1283	96	99	102	106	x	x	95	7.5	NS
C. Campden	73	744	92	113	121	111	106	x	x	6.7	NS
Woodstock	90	1557	107	100	107	107	x	98	x	6.3	NS
Oxford	72	2469	101	90	89	93	x	85	x	3.5	NS
Thame	46	857	90	114	99	86	x	93	x	9.8	NS
Wokingham	-	-	-	-	-	-	-	-	-		
Wisbech	61	1391	107	102	98	91	x	91	x	4.5	NS
Outwell	50	666	113	93	97	102	x	x	102	10.1	NS
Swaffham	27	222	86	118	95	104	107	x	x	9.4	NS
Mean of all sites			100	105	99	99	102	94	96		

* Lenacil @ 2 kg/ha applied in March

ø except Evesham - lenacil 1 kg/ha; Wisbech and Outwell - chloroxuron 4.5 kg/ha

x no treatment

\- not assessed

Table 5

The average weight of coloured fruit (as % of control)

Location	Control* (g/fruit)	Lenacil^ø 2 kg/ha	Pendimethalin 2 kg/ha			Pendimethalin 4 kg/ha			S.E. ± %	LSD (p = 0.05)
			Feb	Mar	Apr	Feb	Mar	Apr		
Chelmsford	11.13	102	98	95	101	x	x	101	3.2	NS
Billericay	8.87	97	101	96	98	x	97	x		
Upminster	8.70	92	94	90	90	93	x	x	4.8	NS
Stow	9.10	94	89	88	87	92	x	x		
Evesham	-	-	-	-	-	x	-	x		
Worcester	9.71	99	90	95	100	x	x	88	4.5	NS
Alcester	-	-	-	-	-	x	-	x		
Stratford	9.33	107	96	92	82	x	x	76	4.7	14.4
C. Campden	10.15	94	96	92	90	94	x	x	1.4	NS
Woodstock	7.45	102	104	105	96	x	99	x	3.1	NS
Oxford	10.28	76	86	86	107	x	114	x	3.1	NS
Thame	8.01	101	101	107	98	x	105	x	4.0	NS
Wokingham	13.79	84	91	87	-	x	92	x	6.3	NS
Wisbech	9.33	104	103	92	94	x	94	x	4.0	NS
Outwell	7.09	106	107	105	97	x	x	94		
Swaffham	7.46	103	100	100	105	108	x	x		
Mean of all sites	-	97	97	95	96	97	100	89		

* Lenacil @ 2 kg/ha applied in March

ø except Evesham - lenacil 1 kg/ha; Wisbech and Outwell - chloroxuron 4.5 kg/ha

x no treatment

\- not assessed

appear to have affected the crop response to pendimethalin.

The results of this series of experiments, together with those reported earlier, indicate that pendimethalin can be used safely in strawberries, even though it reduces leaf growth. In these experiments there was no competition from weeds on either the pendimethalin treatments or the standards with which they were compared. Where pendimethalin controls weeds not normally controlled by alternative herbicides any direct effect of herbicide on fruiting will probably be offset by the elimination of weed competition.

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THE EFFECT OF APPLICATION TIMING AND FORMULATION ON THE TOLERANCE OF STRAWBERRIES TO OXADIAZON

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Summary Different formulations of oxadiazon were applied to established strawberries in winter or spring. Spring application of 2 and 4 kg/ha e.c. resulted in leaf necrosis and stunting shortly after treatment and fruit yield reduction but growth by the end of the year and yield the following year were unaffected. Where treatments were repeated in the second year effects were no more severe. Application date had a greater effect than dose on fruit yield.

Application of a w.p. formulation at three dates in spring caused less leaf stunting and fruit yield reduction than the e.c. Neither the e.c. nor granules applied in December had any effect on subsequent growth or yield. Granules caused less damage than the e.c. when applied in February or March.

There was no difference in the effect of oxadiazon on cv. Cambridge Favourite, Gorella and Montrose.

It is concluded that oxadiazon may be useful as a spot treatment for *Convolvulus arvensis* control in strawberries. In addition a dormant season treatment may be useful in conjunction with simazine in the autumn to give annual weed control through to harvest.

INTRODUCTION

Oxadiazon has been used in certain perennial crops in the British Isles for some years (May & Baker, 1980). It is recommended for the control of *Convolvulus arvensis* and *Calystegia sepium* and, pre-emergence, for long-term control of simazine-resistant annual weeds. Thus it could have a place in strawberries for use against *Convolvulus arvensis*, for which there is no recommended spring treatment, and, for use in conjunction with autumn simazine treatment, to control annual weeds till after fruit harvest.

Pot experiments on strawberries showed that although oxadiazon was very damaging when applied to the foliage, plants subsequently recovered; it was not toxic when applied to the roots of plants growing in sand (Clay, 1980). In field experiments treatment of young plants, cv. Cambridge Favourite in spring caused leaf necrosis and stunting but by the end of the year growth was no different from the standard safe treatment (Clay, 1980).

In order to assess the potential for oxadiazon in strawberries further experiments were carried out to study the tolerance of established crops in relation to date of application and formulation and to compare the response of three cultivars.

METHOD AND MATERIALS

Four experiments were carried out from 1977-1979 at Begbroke Hill on a sandy loam soil with 2-3% organic matter and pH 6-7. The strawberries were grown as matted rows 0.75 m wide. Experiments were laid out as randomised blocks with four replicates and with two lenacil treatments per block. Lenacil (2 kg/ha a.i.) is recommended for strawberries on this soil type (Fryer and Makepeace, 1978) and was used as a standard with which to compare oxadiazon. Crop cultivars and age at treatment, plot length and herbicide spray volume are shown in Table 1.

Table 1

Crop age and cultivar, plot length and spray volume rate in four field experiments

	Experiment Number			
	1	2	3	4
Cultivar	Gorella	Cam. Favourite Gorella, Montrose	Gorella	Cambridge Favourite
Crop age at treatment (years)	1, 2	1	2	2
Plot length (m)	2.0	3.2	2.0	2.85
Spray volume (l/ha)	400	527	527	527

The herbicide formulations used were: oxadiazon, 25% e.c., 60% w.p. and 2% granules; lenacil 80% w.p. Sprays were applied with a pressurized knapsack sprayer using 8004 Tee jets at a pressure of 2 bars; granules were applied from a hand-held 'pepper pot' dispenser. The treatments and application dates are shown in Tables 2-5. The few weeds that grew were hand weeded at the young seedling stage. Paraquat was used as necessary to control runners developing in the alleys. Experiments 2, 3 and 4 received an overall spray of simazine (0.75 kg/ha) in September 1978; experiment 3 was sprayed overall with lenacil (2 kg/ha) in April 1979.

Crop vigour was assessed visually at intervals after treatment using a 0-9 scoring scale (0 = plant dead, 3 = very stunted, still growing; 5 = 50% growth reduction; 7 = readily distinguishable growth reduction; 9 = plant normal). In 1977 fruit yield was assessed by a single harvest of all fruit when most fruit was ripe. In 1978/9 several picks of ripe fruit were made. In experiments 2 and 3 the number of rooted runners was counted in 2 m of row/plot in March 1978 and 1979.

RESULTS

Experiment 1

Oxadiazon applied at 2 and 4 kg/ha as the e.c. in late March or early May 1977 caused severe leaf necrosis and stunting (Table 2). Fruit yield was reduced by 32 and 42% by March treatments and by 64 and 71% by May treatments, compared with the lenacil treatment. Where oxadiazon applications were not repeated in 1978 but lenacil applied instead yield was similar or slightly higher than on plots receiving lenacil in both years. Where oxadiazon was reapplied at two dates in April 1978, leaf growth was stunted temporarily and fruit yield reduced by 19% by mid April treatment and 25% by late April application compared with the lenacil standard. Yield reduction mainly resulted from lower quantities in the last of three picks.

Experiment 2.

Oxadiazon (2 kg/ha) applied as the e.c. in mid- and late-April 1978 caused leaf necrosis and stunting on all three cultivars; there was a full cover of normal leaves

Table 2

The effect of oxadiazon(e.c.) applied in spring for 1 or 2 years to established strawberries cv. Gorella (Experiment 1)

Herbicide ‡ and dose (kg/ha)	Application dates	1977 Vigour score+ 21/4	1977 Vigour score+ 20/5	1977 Vigour score+ 25/6	1977 Total Fruit yield+	1978 Vigour score+ 8/5	1978 Vigour score+ 22/5	1978 Vigour score+ 23/6	1978 Fruit yield+ 28/6	1978 Fruit yield+ 6/7	1978 Fruit yield+ 12/7	1978 Fruit yield+ Total
(Oxadiazon 2	24/3/77	25***	46***	67***	68***							
(Lenacil 2	12/4/78					100	101	100	92	103	96	98
(Oxadiazon 4	24/3/77	25***	34***	67***	58***							
(Oxadiazon 2	12/4/78					44***	45***	100	115	94	62***	81***
(Oxadiazon 2	2/5/77	-	43***	67***	36***							
(Lenacil 2	12/4/78					100	101	100	113	113*	107	110
(Oxadiazon 4	2/5/77	-	37***	53***	29***							
(Oxadiazon 2	29/4/78					56***	37***	100	105	86*	58***	75***
(Lenacil 2	24/3/77	100	100	100	100							
(Lenacil 2	12/4/78					100	100	100	100	100	100	100
(Actual values, lenacil)		(8.0ø)	(8.7)	(9.0)	(1.0≠)	(9.0)	(8.9)	(9.0)	(0.5≠)	(1.2)	(1.7)	(3.4)
S.E.± oxadiazon treatments		2.4	2.4	0.8	5.6	1.1	2.2	1.9	9.1	4.4	6.3	4.0
SED from lenacil standard		3.3	2.9	1.1	7.9	1.4	2.7	2.1	12.3	6.2	7.6	5.0

‡ Herbicides bracketed were applied to the same plots in successive years

\+ As % lenacil standard
ø Vigour score, 0-9 scale, 0 = dead, 9 = healthy
*, **, *** indicates values significantly different from lenacil standard at P = 0.05, 0.01, 0.001
≠ Fruit yield, kg/m^2

Table 3

The effect of oxadiazon as the e.c. applied to three strawberry cultivars in spring 1978 (Experiment 2)

Herbicide and dose (kg/ha)	Application date	Cv.+	Vigour score‡			Fruit yield‡						Rooted runners‡
			25/4	30/5	23/6	26/6	28/6	5/7	11/7	20/7	Total	12/3/79
Oxadiazon 2	12/4	C	35***	51***	81**	99	101	70	63**	62*	67**	114
		G	46***	51***	78***	81	60	78	82	72	77	112
		M	44***	48***	79***	54*	79	89	87	69	76*	94
		Mean	42***	50***	79***	78*	80*	79**	77**	67***	73***	107
Oxadiazon 2	29/4	C	106	51***	100	53**	77	76	73*	75	74*	116
		G	102	49***	102	60*	59	59*	67*	61*	62**	106
		M	97	45***	103	61*	80	85	69*	69	71*	86
		Mean	102	48***	102	58***	72**	73**	73***	68**	69***	103
Lenacil 2	11/4	all cv.	100	100	100	100	100	100	100	100	100	100
(Actual values, lenacil)		C	8.5●	7.4	8.2	0.1ø	0.1	0.5	0.6	1.0	2.3	68≠
		G	8.6	8.7	8.6	0.2	0.2	0.7	0.6	0.6	2.3	68
		M	9.0	8.9	8.2	0.1	0.1	0.5	0.8	1.9	3.4	58
SE ± cv. x oxadiazon			2.7	3.0	4.2	12.6	19.1	12.4	9.6	13.2	8.8	9.5
SED from lenacil standard			3.3	4.0	4.6	15.4	23.4	15.2	13.5	18.7	10.7	11.3

+ Cultivars: C, Cambridge Favourite; G, Gorella; M, Montrose
‡ Expressed as % lenacil standard
● Vigour score, 0-9 scale; 0 = dead, 9 = healthy
ø Fruit yield, kg/m^2
≠ Rooted runners, number/m^2
*, **, *** indicate values significantly different from lenacil standard at P = 0.05, 0.01, 0.001

Table 4

The effect of e.c. and w.p. formulations of oxadiazon applied at different dates in spring 1978 to established strawberries cv. Gorella (Experiment 3)

Herbicide	Dose (kg/ha)	Formulation	Application date	Vigour score$^+$			Fruit yield$^+$ Total 1978	Rooted runners$^+$ 8/3/79	Fruit yield$^+$ Total 1979
				23/4	22/5	23/6			
Oxadiazon	2	w.p.	6/3	55***	67***	89	94	104	108**
"	4	"	"	44***	55***	74***	80***	116**	112***
Oxadiazon	2	e.c.	6/3	41***	63***	83*	84**	90	100
"	4	"	"	58***	44***	83*	76***	99	105
Oxadiazon	2	w.p.	15/4	63***	55***	94	88*	89*	99
"	4	"	"	58***	44***	89	81***	105	107*
Oxadiazon	2	e.c.	15/4	41***	52***	83*	77***	111*	109**
"	4	"	"	39***	44***	74***	63***	112*	102
Oxadiazon	2	w.p.	28/4	100	47***	94	89*	104	100
	4	"	"	100	44***	91	76***	98	105
Oxadiazon	2	e.c	28/4	100	44***	89	78***	106	105
	4	"	"	100	33***	74***	60***	111*	107*
Lenacil	2	w.p.	6/3	100	100	100	100	100	100
(Actual values, lenacil)				8.9●	8.9	8.7	12.7ø	69≠	8.3ø
S.E.± oxadiazon treatments				1.8	1.4	5.1	4.2	4.0	2.1
SED from lenacil standard				2.0	1.7	6.0	4.8	5.2	2.8

$^+$ values as % lenacil standard

● 0 - 9 scale   ø Fruit yield, kg/plot   ≠ Rooted runners, number/m^2

*, **, *** indicate values significantly different from lenacil standard at P = 0.05, 0.01, 0.001

Table 5

The effect of e.c. and granular (gr) formulations of oxadiazon applied at different dates in winter and early spring 1979 to established strawberries cv. Cambridge Favourite (Experiment 4)

Herbicide	Dose (kg/ha)	Formul-ation	Application date	Vigour score^{+} 15/5	12/7	Fruit yield^{+} 3/7	9/7	17/7	Total	Fruit size^{+} 3/7	9/7
Oxadiazon	0.5	e.c.	20/12/78	102	100	126	101	91	98	103	93
	1.0	"	"	102	100	114	103	93	99	96	92
	2.0	"	"	90	100	84	89	91	89	99	97
	2.0	gr	"	102	100	96	102	101	101	105	99
	0.5	e.c.	23/2/79	102	100	86	103	101	101	94	101
	1.0	"	"	87	100	111	98	91	96	97	92
	2.0	"	"	72***	100	117	97	90	95	90*	94
	2.0	gr	"	81*	100	126	96	92	96	98	92
	0.5	e.c.	30/3/79	96	100	77	96	103	98	97	101
	1.0	"	"	66***	94*	92	83**	79*	82**	88*	83**
	2.0	"	"	51***	83***	108	84**	77*	82**	89*	97
	2.0	gr	"	78*	94*	126	99	68***	86*	107	92
Lenacil	2.0	w.p.	30/3/79	100	100	100	100	100	100	100	100
(Actual values, lenacil)				8.3ø	9.0	0.9≠	6.5	6.5	13.9	0.9ł	0.6
S.E. ±	oxadiazon treatments			5.6	2.5	21.5	4.8	7.5	4.9	3.9	4.8
SED	from lenacil standard			6.5	2.9	24.9	5.5	8.7	5.6	4.5	5.6

$^{+}$ values as % lenacil standard
ø vigour score, 0-9 scale
≠ fruit yield, kg/plot
ł 100 berry wt, kg
*, **, *** indicates values significantly different from lenacil standard at P = 0.05, 0.01 and 0.001

by fruit harvest although the leaf canopy was thinner with the earlier treatment date (Table 3). Fruit yield was reduced by 27% by mid-April treatment and 31% by late April application compared with the lenacil treatment.

There were no significant differences in total yield reduction between cultivars and no differences between oxadiazon and lenacil in the number of rooted runners present the following winter.

Experiment 3

When applied in early March, mid-April and late April 1978, a w.p. formulation of oxadiazon caused less leaf scorch and stunting than the e.c. formulation (Table 4), but the damage on all treatments was largely outgrown by fruit harvest. The w.p. resulted in less yield reduction than the e.c. irrespective of application dates; yields from the 2 kg/ha w.p. applications were not significantly different from the safe standard at the first treatment date. There was greater yield reduction with the highest dose of both formulations at all treatment dates and from the second and third treatment date compared with the first. Oxadiazon had no consistent effect on the date of fruit ripening or, generally, on long-term growth (as indicated by a count of the number of rooted runners in March 1979). Yields in 1979 were slightly increased by some of the oxadiazon treatments.

Experiment 4

None of the oxadiazon treatments applied in December had any adverse effects on crop growth or yield compared with the standard lenacil treatment (Table 5). With February treatments both formulations of oxadiazon (2 kg/ha) caused leaf stunting in spring; this was outgrown by fruit harvest with no yield reductions. There was no damage from lower doses.

Oxadiazon as the e.c. at 1 and 2 kg/ha applied in late March caused temporary stunting of the crop in spring and 18% yield reduction. The granular formulation at 2 kg/ha caused less leaf stunting than the e.c. and 14% yield reduction. The e.c. formulation at 0.5 kg/ha had no adverse effect.

Where yields were reduced this resulted from lower quantities of fruit in the last one or two picks. Fruit size was slightly reduced by some of the e.c. applications at 1 and 2 kg/ha in February and March.

DISCUSSION

The damage and complete recovery from spring treatments with oxadiazon on established crops cv. Gorella was similar to that found in earlier work with young plants of cv. Cambridge Favourite (Clay, 1980). Similarly application timing had a greater effect on crop response than dose, the later spring application being the most damaging. Oxadiazon damage on strawberries occurs through foliar rather than root uptake (Clay, 1980) so applications in the dormant period would be more likely to be safe. Autumn treatments have been reported as safe in Italy (Marocchi, 1975). The maximum degree of leaf damage caused by treatments from March to early May was not very different, thus the greater effect of later treatments on yield probably resulted from the short interval between application and swelling of the fruit. Where oxadiazon was applied in two successive years the smaller yield reductions in the second year may have been due to differences in conditions between years rather than increased tolerance of the crop. Applications at about the same times to an adjacent crop, which had not been treated before, gave similar yield reductions (Table 4). The results suggest that repeated applications may not lead to increased crop losses.

The yield increases recorded in the year after some oxadiazon treatments may have been due to an effect of the treatments on runner development. The reduction in foliage may have afforded better conditions for runner rooting and growth. The numbers of rooted runners recorded in winter following these treatments tended to be higher than the lenacil standard. The absence of differential tolerance between the cultivars was in contrast to results with two other recently tested herbicides, ethofumesate and 3,6-dichloro-picolinic acid (Clay, 1979; Bailey and Clay, 1980).

Formulation of oxadiazon had a pronounced effect on response with both w.p. and granules being safer than the e.c. Similar results were found with comparisons of w.p. and e.c. formulations of oxyfluorfen on strawberries (Clay, unpublished data). Where damage did occur with the granular formulation this was probably due to uptake from granules lodging on leaves and in the plant crowns.

The results suggest that oxadiazon may be useful in strawberries as a spring treatment for the control of Convolvulus arvensis, for which there is no recommended treatment at present. Although there may be short-term leaf damage and crop loss, the consequence of leaving the weed to spread would be worse. Damage can be minimised by the use of spot treatments. Applications in successive years may be needed to control C. arvensis and a 4 kg/ha dose be preferable (Davison, 1972). In view of the effect soil residues may have on some annual crops treatment should be avoided in the year of grubbing a plantation.

Oxadiazon is recommended in other fruit crops for the control of simazine-resistant weeds (May and Baker, 1980). Thus application of oxadiazon with or following simazine in the autumn may give control of annual weeds through to harvest and avoid the need for a residual herbicide in the spring.

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THE INFLUENCE OF APPLICATION DATE AND GROWING SYSTEM ON THE RESPONSE OF STRAWBERRIES TO PROPYZAMIDE, SIMAZINE AND TRIETAZINE + SIMAZINE

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Summary Propyzamide was applied at low doses to young strawberry crops in winter. A rate of 0.8 kg/ha caused crop damage from two out of six applications but 0.4 kg/ha was safe. The weed situations where such applications may be useful are discussed.

The effect of propyzamide and trietazine + simazine on strawberries grown as spaced plants or matted rows was compared with a recommended treatment, simazine. Propyzamide (1.4 kg/ha) caused severe plant stunting on matted rows but no yield reductions compared with simazine applied in November. Trietazine (1.36 kg/ha) + simazine (0.19 kg/ha) on matted rows was safe in November but in March damaged plants and reduced yield. Spaced plants were not affected. Simazine (1.5 kg/ha) on matted rows in November damaged small plants in spring and resulted in 20% lower yield than trietazine + simazine. It is suggested that trietazine + simazine may not always be safe on 1 year-old crops in spring and the recommended dose of simazine on young matted-row crops in late autumn may be too high.

There was no difference in the response of the cv. Cambridge Favourite, Gorella and Montrose to trietazine + simazine applied in spring.

INTRODUCTION

Propyzamide is recommended at 1.4 kg/ha for perennial grass weed control in strawberries. Because of the possibility of crop damage the recommendation is restricted to use on medium to heavy soils and on established crops grown as spaced plants. The time of application is also limited to the October-December period. A lower dose (0.8 kg/ha) can be used for annual grass weed control on crops grown as spaced plants and matted rows but with the same limitations for soil type and timing (PBI, 1980). Field trials on crop tolerance have demonstrated the variability of response (Sumpter, 1970; Clarke and Sumpter, 1972); low doses have sometimes caused damage (Cameron, 1972, Uprichard, 1972) and high doses on matted rows in Scotland been safe (Lawson and Wiseman, 1975). Variable response to propyzamide has been a problem in usage in Canada (Jensen, 1977).

Since much of the strawberry crop in the U.K. is grown as matted rows on lighter soils and annual grasses are a severe problem in young crops there has been much interest and some growers risk use of propyzamide outside the recommendations. In order to obtain more information on the effect of dose and timing on response, two trials were carried out from 1975 to 1978.

Trietazine + simazine is recommended for pre-emergence weed control of annual weeds in established crops (Fryer and Makepeace, 1978). Younger crops vary in susceptibility to the herbicide (Clay, 1978) and there have been reports of appreciable leaf damage from spring treatments on established crops (Jones, A.G., personal communication). An experiment was therefore carried out to compare the effect of applying trietazine + simazine in November and March to plants grown as spaced plants or matted rows using simazine and propyzamide as standards for comparison. In another trial the response of three cultivars to trietazine + simazine was compared.

METHOD AND MATERIALS

The experiments were carried out at Begbroke Hill on a sandy loam soil of the Sutton/Badsey series with a 2-3% organic matter content and pH 6-7. The herbicides used were lenacil (80% w.p.), propyzamide (50% w.p.), simazine (50% w.p.) and trietazine + simazine (50% w.p. containing 43.75% trietazine + 6.25% simazine; doses given below are for the total a.i.). All herbicide treatments were applied using a pressurized knapsack sprayer.

Experiment 1 Strawberry runners, cv. Cambridge Favourite, were planted on 15/10/75 with nine plants in metre square plots. The trial was laid out as randomised blocks with four replicates. Four lenacil treatments were used at a rate recommended on young strawberries (Fryer and Makepeace, 1978) as a safe standard with which the propyzamide treatments were compared. Herbicides were applied at the dates and rates shown in Table 1 using a screened spraying frame (Blair et al., 1975). The volume rate was 400 l/ha. Any weeds developing on the plots were removed by hand at the small seedling stage.

Crop vigour was assessed visually at intervals after treatment using a 0-9 scoring scale (0 = plant dead, 5 = 50% growth reduction, 9 = plant normal). Fruit yield was measured by a single pick when most of the fruit was ripe. Stolons and runners were cut off at intervals during summer and autumn and fresh weight recorded. Number of plants/plot and crown numbers/plot were recorded in autumn.

Experiment 2 Runners, cv. Gorella were planted in March 1977 in single row plots 3.2 m long and allowed to form matted rows. Weeds were controlled by applications of lenacil (2 kg/ha) after planting and simazine (1.5 kg/ha) in early September. The trial was laid out as randomised blocks with three replicates and two lenacil treatments as a safe standard. Experimental treatments at the dates and doses listed in Table 2 were applied at a volume rate of 400 or 530 l/ha. Crop vigour was assessed as above and fruit yield recorded at four picking dates. The number of rooted runners on 2, 1 x 0.75 m quadrats/plot was recorded on 12/3/79.

Experiment 3 Runners, cv. Gorella were planted in March 1976, 0.5 m apart for spaced plant rows and 0.25 m for matted rows. The trial was laid out as randomised blocks, with 3 replicates, with plots split for growing system. Each plot was 9 m long. Lenacil (2 kg/ha) was applied overall after planting.

Herbicide treatments were applied at the dates and rates shown in Table 3. Crop vigour and fruit yield were recorded as in Experiment 2.

Experiment 4 Runners, cv. Cambridge Favourite, Gorella and Montrose were planted in March 1977 with the same plot length, overall herbicide treatments and growing system as in Experiment 2. The trial was laid out as randomised blocks with four replicates, main plots split for crop cultivars, and two lenacil treatments as a safe standard.

Experimental treatments were applied at the date and rates shown in Table 4 at a volume rate of 530 l/ha. Crop vigour, fruit yield and runner growth were assessed as in Experiment 2.

RESULTS

Experiment 1 Propyzamide at 0.4 kg/ha applied to autumn planted strawberries in October, December and February had no effect on crop growth or subsequent yield (Table 1). 0.8 kg/ha applied post-planting caused stunting in spring, 20% yield reduction and subsequent reduction in runner production and crown numbers. 0.8 kg/ha applied in December caused stunting in spring, no effect on fruit yield or runner production but reduced crown numbers the following winter. The same dose applied in February had no adverse effect.

Table 1

The effect of winter applications of propyzamide on autumn-planted strawberries cv. Cambridge Favourite (Experiment 1)

Application date	Dose (kg/ha)	Vigour score (0-9 scale) 10/5/76	4/6/76	Fruit yield 21/6/76	Runner wt Autumn 76	Plant no 16/11/76	Crown no 16/11/76
				Values as % lenacil standard			
17/10/75	0.4	8.5	8.2	100	88	100	86
	0.8	6.5***	6.5***	80*	72*	100	78**
8/12/75	0.4	8.5	8.7	91	104	100	94
	0.8	6.7**	8.0	108	87	100	77**
16/2/76	0.4	8.5	8.5	92	81	100	97
	0.8	7.7	8.2	111	99	100	98
Lenacil 17/10/75 + 1/4/76	2.0	8.0	8.1	100	100	100	100
(actual values, lenacil)				0.52 kg/m^2	0.49 kg/m^2	9/plot	25/plot
SE ±		0.38	0.40	7.9	10.7	-	7.4
SED from lenacil standard		0.42	0.45	8.8	11.9	-	8.3

*, **, ***, indicates values significantly different from the lenacil standard at P = 0.05, 0.01, 0.001.

Experiment 2 On a spring planted crop, propyzamide (0.8 and 1.4 kg/ha) applied in November was safe (Table 2). 0.8 kg/ha applied in January and early March caused severe stunting in spring but no reduction in crop or long-term effect on growth. 1.4 kg/ha applied at the second two dates caused severe stunting in spring, 50-60% crop reduction but had no effect on subsequent growth. 0.8 and 1.4 kg/ha applied in mid-April caused temporary stunting of plants but there was no subsequent yield or growth reduction.

Experiment 3 Propyzamide (1.4 kg/ha) applied in November and March caused severe stunting of plants in spring, particularly on smaller rooted runners in the matted rows (Table 3). Fruit trusses were reduced in length but there was no reduction in total fruit yield compared with the standard simazine treatment. Simazine (1.5 kg/ha) applied in November had no observable effect on spaced plants in spring but caused leaf chlorosis and necrosis on smaller rooted runners on the matted rows. Fruit yield from matted rows was 20% below the corresponding November trietazine + simazine treatment. Simazine applied in March caused leaf necrosis on spaced plants but no yield reduction. Matted rows were severely damaged and yield reduced by 50% compared with the November treatment. Trietazine + simazine applied in November had no adverse effect on spaced plants; on matted rows there was some leaf necrosis in spring on small rooted runners but yields were 20% above the standard simazine treat-

Table 2

The effect of propyzamide applied at four dates in winter and spring to strawberries cv. Gorella (Experiment 2)

Application date	Dose (kg/ha)	Vigour score (0-9 scale) 25/4/78	30/5/78	23/6/78	Fruit yield (% lenacil standard) 26/6/78	30/6/78	5/7/78	12/7/78	Total	Runner number 12/3/79
28/11/77	0.8	9.0	8.3	7.3	91	83	98	98	93	87
	1.4	9.0	8.3	7.0	92	106	90	106	100	90
6/1/78	0.8	5.7***	5.0***	5.3***	100	80	94	72	84	108
	1.4	4.3***	4.3***	4.0***	67	57***	50**	54*	56***	89
6/3/78	0.8	6.3***	5.3***	6.3**	127	95	73	84	92	99
	1.4	5.7***	4.0***	4.7***	101	59***	47**	42**	58**	94
15/4/78	0.8	9.0	6.7**	8.0	112	93	108	107	104	93
	1.4	9.0	5.7***	6.7*	103	101	94	83	94	90
Lenacil 15/4/78	2 kg/ha	9.0	8.3	8.0	100	100	100	100	100	100
				Actual value (kg/plot)	0.2	0.3	0.2	0.4	1.1	123/ plot
SE ±		0.21	0.43	0.45	12.6	9.5	14.9	13.4	8.4	10.0
SED from lenacil standard		0.26	0.52	0.55	15.4	11.7	18.3	16.5	10.5	12.3

*, **, *** indicates values significantly different from lenacil standard at P = 0.05, 0.01, 0.001

Table 3

The effect of propyzamide (1.4 kg/ha) simazine (1.5 kg/ha) and trietazine + simazine (1.55 kg/ha) on strawberries grown as spaced plants(S) and matted rows(M) (Experiment 3)

Herbicide	Application dateø	Vigour score (0-9 scale) 21/4/77 S	21/4/77 M	20/5/77 S	20/5/77 M	28/6/77 S	28/6/77 M	Fruit yield (%)+ 6/7/77 S	6/7/77 M	11/7/77 S	11/7/77 M	Total S	Total M
Simazine	Nov.	9.0	7.0	9.0	7.0	9.0	7.7	100 0.17‡	100 0.43	100 0.41	100 0.63	100 0.58	100 1.06
	Mar.	8.3*	6.0**	7.7***	5.0***	7.0***	5.7***	97	38***	102	56**	101	49***
Propyzamide	Nov.	6.7***	6.0**	7.0***	6.0***	7.0***	6.7**	106	98	89	94	94	95
	Mar.	7.6***	7.0	8.0**	7.0	6.7***	5.3**	133	114	83	80	97	93
Trietazine + simazine	Nov.	9.0	7.3	9.0	8.7***	9.0	9.0	114	139***	94	107	100	120*
	Mar.	7.7***	6.0**	8.3*	6.3*	9.0	6.0***	121	47***	81	82	92	68**
SE ±		0.22		0.19		0.21		17.8	6.9	13.1	8.6	12.5	6.8
SED from November simazine		0.30		0.27		0.30		25.1	9.7	18.5	12.1	17.6	9.6

øApplication dates 10 November 1976 and 11 March 1977

‡Actual yield, November simazine, kg/m row

+Fruit yield as % November simazine

*, **, *** indicates values significantly different from November simazine treatment at P = 0.05, 0.01, 0.001.

ment. Spaced plants treated in March developed slight leaf necrosis but yield was not affected; matted rows showed severe leaf necrosis on smaller plants and 32% yield reduction.

Table 4

The effect of applications of trietazine + simazine on 11/4/78 on the strawberry cultivars Cambridge Favourite (C), Gorella (G) and Montrose (M) (Experiment 4)

Herbicide	Dose (kg/ha)	cv.	Vigour score (0-9 scale) 25/4/78	30/5/78	23/6/78	Total fruit yield % lenacil standard 26/6-20/7/78	Rooted runners % lenacil standard 12/3/79
Trietazine + simazine	1.37	C	7.7*	6.5*	7.2	86	97
		G	7.5***	7.0***	7.5	87	94
		M	8.5	6.5***	7.0*	82	75*
"	2.74	C	7.7*	4.7***	6.2**	57***	97
		G	7.0***	5.2***	6.2***	58**	95
		M	8.5	5.5***	6.0***	62**	89
Lenacil	2.00	C	8.5	7.4	8.2	100 (2.3)ø	100 (69)‡
		G	8.6	8.7	8.6	100 (2.3)	100 (68)
		M	9.0	8.9	8.2	100 (3.4)	100 (58)
SE ±			0.24	0.29	0.40	8.8	9.9
SED for comparisons with lenacil			0.30	0.36	0.50	10.7	11.3

*, **, *** indicates values significantly different from the lenacil standard for that cv. at P = 0.05, 0.01, 0.001.
ø actual values for lenacil standard, kg/m^2 ‡ number/m^2

Experiment 4 Trietazine + simazine (1.37 kg/ha) applied in spring to 1-year-old matted rows caused leaf chlorosis and necrosis on all three cultivars (Table 4). Compared with the standard lenacil treatment fruit yield was reduced by 14-18% but not significantly and there were no significant differences between cultivars. Subsequent growth (assessed by a count of rooted runners the following winter) was similar to the standard treatment except for a 25% reduction in numbers with cv. Montrose. The 2.74 kg/ha rate caused severe leaf necrosis and a similar yield reduction (38-43%) on all cultivars but had no effect on subsequent growth.

DISCUSSION

The experiment with propyzamide confirmed previous reports that the high dose (1.4 kg/ha) can be toxic to plants grown as matted rows on a sandy loam soil, although effects on yield were not severe. The 0.8 kg/ha treatment was generally safe although slight yield and/or long-term growth reduction occurred with two out of the six applications. Uprichard (1972) obtained similar results with low doses. The widely-reported variations in the effect of propyzamide on both crop and perennial weeds are probably the result of differences in such factors as rainfall after application, soil organic matter and surface trash but there has been no detailed investigation of this aspect. Jensen (1978) found no consistent effect of post-harvest mowing and subsequent mulching on response to propyzamide applied in autumn in Canada, though in grower usage mowing appeared to increase chances of damage. Propyzamide is not recommended in the UK for use on strawberries in winter after December (Fryer and Makepeace, 1978) but there was no consistent evidence in the trials reported here of appreciably more damage from the later applications.

Since the safety of the low doses on young crops is uncertain no general recommendation can be made but there may be occasions where use at growers risk is advisable. This situation occurs where Poa annua is becoming established in young crops in early winter; handweeding is ineffective and a possible alternative herbicide, ethofumesate, is only recommended on established crops of cv. Cambridge Favourite (Clay, 1980). The use of the lower dose may also be possible; the 0.4 kg/ha dose was safe at all dates in Experiment 1. Doses of 0.5 kg/ha are recommended for annual grass control in oil seed rape (PBI, 1980) and this treatment has been used successfully on strawberries in Kent. Similar considerations regarding growers risk treatments apply with spot treatment of the high dose on susceptible weeds such as Agropyron repens, Ranunculus repens and Rumex acetosella growing in matted rows. For such broadleaved weeds, 2,4-D post-harvest is the only alternative treatment (Davison and Bailey, 1978). One disadvantage with propyzamide treatments is that the full effects are not shown until late spring, so if replanting is necessary it will be seriously delayed.

The results of the experiment with trietazine + simazine on crops with different growing systems illustrates the important effect of plant size. It suggests that where a matted row contains many small runners, as frequently occurs on one-year-old crops, trietazine + simazine may not always be a safe spring treatment. But the trial also demonstrates that the recommended simazine treatment (1.5 kg/ha in autumn) can be damaging to relatively young matted-row crops; the yield reduction from this treatment compared with trietazine + simazine in November was similar to that from propyzamide. Such simazine damage may not show until the spring and may be accentuated by the spring residual herbicide treatment. The results suggest that a reduced dose of simazine may be advisable on young crops. In years when the autumn is dry and simazine breakdown rate reduced it may sometimes be better to omit the second treatment (Jones, A.G., 1979, personal communication).

The experiment on varietal tolerance of trietazine + simazine suggests there is no difference in response of the two commonly-grown cultivars Cambridge Favourite and Gorella which were used in earlier work on tolerance to this herbicide (Clay, 1978). Differences have been found in the tolerance of these cultivars to other herbicides (Bailey and Clay, 1980; Clay, 1980).

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HERBICIDE PROGRAMMES FOR SPRING-PLANTED STRAWBERRIES

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Summary A series of weed control programmes based on tank-mixes and sequences of herbicides was evaluated in four experiments on strawberry cv. Cambridge Favourite. Several of the components checked early growth, but no programme caused any permanent adverse effects, as judged by crown counts recorded in the following spring. The incorporation of trifluralin before planting enhanced the performance of post-planting residual herbicides on spring-germinating weeds and increased persistence. Of the post-planting treatments, ethofumesate plus a reduced level of lenacil performed as well as lenacil alone at the standard rate, while the addition of chlorthal dimethyl to propachlor improved both efficacy and persistence. Post-emergence application of phenmedipham was an essential component of most programmes, to control weeds surviving herbicide treatment at planting. A mixture of ethofumesate and a reduced rate of phenmedipham gave control of *Poa annua* as well as of broad-leaved weeds and increased the persistence of effects of programmes in which it was included. Several of the programmes kept plots virtually free from weeds until the end of the year.

INTRODUCTION

The number of herbicides marketed in the United Kingdom for use in strawberries has increased considerably in recent years (Clay, 1980). This not only gives greater choice of individual treatment, but also allows consideration of programmes involving tank-mixes and sequences of herbicides to suit different soil types, weed flora and seasonal weather conditions. However, growers have difficulty in gaining information on herbicide programmes, particularly when the components originate from different manufacturers. We have therefore examined the effects of various combinations of herbicide treatments, applied to young plantations, on the crop and on the efficacy and persistence of weed control. The objective was to keep the crop virtually free from weeds during early summer, when young strawberry plants are particularly sensitive to competition from weeds (Lawson & Wiseman, 1976), and preferably until the safe time for application of simazine in late autumn. Treatment of spring-planted crops with simazine is not generally recommended until 6 months after planting (Fryer & Makepeace, 1978).

METHOD AND MATERIALS

Four experiments were carried out at Invergowrie on sandy loam soils with organic matter contents (as determined by loss on ignition) of between 6% and 8%. Plots consisted of single rows of 15 plants of cv. Cambridge Favourite planted 45 cm apart with 90 cm between rows. The crops were trained into matted rows and pegged strings were used to delineate the desired width of row (30 cm on either side of the parent plants). Plot size was 60 cm wide by 6.75 cm long. The young plants were deblossomed; early runners were trained into the rows, but later growth was unrestricted. In autumn, runner plants outside the strings were controlled with directed application of paraquat. Height and spread measurements on parent plants and mean number of runners/plant were recorded during the first growing season; total numbers of crowns within the matted row area were counted in the following spring. Crops were not taken to fruit yield.

Plots were scored for percentage ground cover by weeds at weekly intervals from planting date until the end of the growing season. Weeds growing within the plot boundaries were counted before and after post-emergence herbicides were applied Thereafter, all surviving weeds were hand-hoed. Those emerging subsequently were removed whenever the mean ground cover scores for weeds in a particular treatment programme reached 10%. This was repeated as often as necessary during the remainder of the growing season.

Herbicides were applied by Oxford Precision Sprayer, using fan jets, to a 90 cm band centred on the crop row. Application was made in 600 l water/sprayed ha for all treatments except those involving phenmedipham, which were applied in 225 l. Herbicide dosages were those officially recommended for strawberries, except for the ethofumesate mixtures, which are currently used only in sugar and red beet. Rates and dates of application were as follows:-

Herbicide treatment	kg a.i./ha
Pre-planting	
Trifluralin	1.12
Post-planting	
Lenacil	2.24
Lenacil/ethofumesate	0.56/1.40
Propachlor	4.55
Propachlor/chlorthal dimethyl	4.55/4.50
Post-emergence	
Phenmedipham	1.12
Phenmedipham/ethofumesate	0.80/1.00

Crop diary	1978 (Expts. I & II)	1979 (Expts. III & IV)
Trifluralin incorporated	12 April	27 April
Crop planted	13 April	30 April
Post-planting herbicides	26 April	11 May
Post-emergence herbicides	31 May	3 July
All weeds removed	20 June	10 July

Herbicide mixtures and sequences used as weed control programme treatments are shown in Tables 1 - 4. Treatments in all four experiments were grouped factorially in fully randomised blocks and replicated three times. Additional plots either had no pre- or post-planting treatment or were sprayed only with trifluralin, to provide information on the weed populations with which later treatments had to contend. After preliminary weed counts these plots were sprayed with post-emergence herbicides, assessed again and then hoed. Because of probable adverse effects of competition from weeds on plots given no pre- or post-planting herbicides, the widely-used programme sequence of lenacil applied after planting, followed by phenmedipham applied after weed emergence, was used as a standard against which to assess the phytotoxicity of other herbicide programmes.

RESULTS

Crop tolerance

In 1978, there was no indication of adverse effects of trifluralin. Very heavy rain (35 mm) fell on the day after application of the post-planting herbicides and all except lenacil checked early growth of the crop. Post-emergence treatments were applied to rapidly-growing plants in warm, sunny weather. Phenmedipham caused typical yellowing and the addition of ethofumesate resulted in some blackening and curling of treated leaves. New leaves showed no symptoms of either herbicide. No treatment caused any loss of plants, but height and spread records taken in mid-June (Tables 1 and 2) showed continuing adverse effects in both experiments of herbicide programmes involving propachlor, of trifluralin followed by lenacil/ethofumesate in Expt. I and an overall check by phenmedipham/ethofumesate in Expt. II. Considerable recovery had, however, taken place by mid-August. No significant differences between herbicide programmes or their components could be detected in crown counts taken in the following spring, and no individual programme gave results significantly different from lenacil followed by phenmedipham in either experiment.

In 1979, spring came late after a very hard winter and the crops were not planted until the end of April. There was again no evidence of any adverse effect of trifluralin. Post-planting herbicides were applied in calm, dry conditions to a damp soil surface, before the emergence of any weeds. Warm dry weather followed for several days. Lenacil/ethofumesate and propachlor/chlorthal dimethyl both checked plant growth. Post-emergence herbicides were applied in dry sunny weather and caused only slight yellowing, with some leaf curling on plots treated with phenmedipham/ethofumesate, but no visible check to growth occurred. Records taken in early August and in September showed continuing adverse effects on crop growth of programmes in Expt. III involving lenacil/ethofumesate or propachlor/chlorthal dimethyl (Table 1). These were slowly outgrown as the season advanced and crown counts taken in the following spring showed no significant effects of treatment programmes or their components, nor of individual programmes in comparison with lenacil followed by phenmedipham. In Expt. IV, there was at no time any evidence of differences in growth due to herbicide programmes (Table 2). In Expt. III there was a significant interaction between sequential components of programmes, the only such effect recorded in these experiments.

Weed control

In 1978, all post-planting herbicide treatments except propachlor gave adequate control of *Poa annua* (Table 3), but none was effective in controlling the broad-leaved weed flora, particularly *Viola arvensis*. Where trifluralin had been applied beforehand, weed numbers were lower, but control was still not satisfactory. However, all post-emergence treatments gave excellent control of broad-leaved weeds surviving earlier herbicide treatments. Phenmedipham alone failed to control *P. annua*, but the mixture with ethofumesate removed this species. The main species surviving completed programmes were *V. arvensis* and *P. annua*, while *Polygonum aviculare* was also present on plots treated only with post-emergence herbicides. Ground cover scores taken after completion of the programmes illustrate the excellent levels of weed control obtained. While plots treated only with phenmedipham had to be weeded a further four times in Expt. I and three in Expt. II, several programmes required little or no additional weeding that year. Least persistent effects were those involving propachlor or propachlor/chlorthal dimethyl, unless preceded by trifluralin. Post-emergence application of phenmedipham/ethofumesate also increased the persistent effects of herbicide programmes in addition to being very effective on its own. The main species requiring removal after late June were *P. annua*, *V. arvensis*, *Stellaria media* and *Senecio vulgaris*.

In 1979, *P. annua* was again well controlled by all herbicide programmes. A wider range of broad-leaved species was encountered and differences in performance

Table 1

Expts. I and III - crop records

	Herbicide programme		Expt. I (1978-79)				Expt. III (1979-80)			
Pre-plant	Post-plant	Post-em.	Height x spread mean/plant (cm^2)		Runners /plant	Crowns/ plot	Height x spread mean/plant (cm^2)		Runners /plant	Crowns/ plot
			10 Jun.	18 Aug.	17 Aug.	17 Apr.	7 Aug.	10 Sept.	26 Sept.	22 May
-	L	B	117	335	9.5	419	307	350	11.7	328
-	P	B	84*	294	8.3	356	273	317	9.0	305
-	L+E	B	100	321	8.1	392	239**	338	8.7	320
-	P+C	B	81*	331	8.2	324	251**	286*	8.7	321
T	L	B	101	312	8.8	374	273	326	10.0	343
T	P	B	71**	321	7.9	385	307	347	11.7	351
T	L+E	B	80*	293	7.6	354	201***	256**	7.7*	321
T	P+C	B	86	310	8.0	420	240**	277*	8.7	315
S.E. mean ±			10.5	17.3	0.99	56.1	12.4	17.6	1.22	39.0
Sig. of effects										
Pre-plant			NS	NS	NS	NS	NS	NS	NS	NS
Post-plant			+	NS	NS	NS	+++	+	NS	NS
Interaction			NS	NS	NS	NS	+	+	NS	NS
L v L + E			NS	NS	NS	NS	+++	+	+	NS
P v P + C			NS	NS	NS	NS	++	+	NS	NS
L v P			++	NS	NS	NS	NS	NS	NS	NS
L + E v P + C			NS	NS	NS	NS	NS	NS	NS	NS

Key:
L - lenacil E - ethofumesate
P - propachlor C - chlorthal dimethyl
T - trifluralin B - phenmedipham

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

+, ++, +++ Effect significant at the 5%, 1% or 0.1% level

NS Not significant

Table 2

Expts. II and IV - crop records

	Herbicide programme		Expt. II (1978-79)				Expt. IV (1979-80)			
Pre-plant	Post-plant	Post-em.	Height x spread mean/plant (cm^2)		Runners /plant	Crowns/ plot	Height x spread mean/plant (cm^2)		Runners /plant	Crowns/ plot
			10 Jun.	18 Aug.	17 Aug.	17 Apr.	7 Aug.	10 Sept.	26 Sept	22 May
-	L	B	141	356	11.5	414	313	361	11.7	357
-	P	B	118	349	9.6	309	271	325	9.3	338
T	-	B	145	359	10.6	424	289	360	12.0	301
-	L	B+E	127	353	11.7	503	299	349	11.3	343
-	P	B+E	88**	349	9.8	445	294	368	11.7	303
T	-	B+E	105*	342	9.3	379	324	353	11.0	389
S.E. mean ±			10.7	24.5	0.78	43.9	29.4	33.0	0.99	25.0
Sig. of effects										
Pre- or post-plant			+	NS	NS	NS	NS	NS	NS	NS
Post-em.			++	NS	NS	NS	NS	NS	NS	NS
Interaction			NS	NS	NS	NS	NS	NS	NS	NS
L v P			+	NS	+	NS	NS	NS	NS	NS
L v T			NS	NS	NS	NS	NS	NS	NS	NS
T v P			NS	NS	NS	NS	NS	NS	NS	NS

Key:
L - lenacil
P - propachlor
T - trifluralin

B - phenmedipham
E - ethofumesate

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

+, ++ Effect significant at the 5% or 1% level

NS Not significant

Table 3

Weed records

Herbicide programme			Nos./m^2						Nos./m^2					
Pre-plant	Post-plant	Post-em.	Poa annua		Annual dicots		% ground cover 20 June*	No. extra weedings by 31 Dec.**	Poa annua		Annual dicots		% ground cover 9 July*	No. extra weedings by 31 Dec.**
			a	b	a	b			a	b	a	b		
							Expt. I						Expt. III	
-	-	B	82	74	117	32	19	4	44	31	27	22	22	2
-	L	B	0	0	60	4	1	1	0	0	3	2	1	0
-	P	B	10	5	95	5	3	3	1	2	11	8	5	2
-	L+E	B	0	0	46	2	1	1	0	0	4	2	4	1
-	P+C	B	5	2	49	3	1	2	1	1	2	1	1	1
T	-	B	2	3	81	8	2	3	4	6	10	8	5	1
T	L	B	2	0	37	2	<1	1	0	0	1	1	<1	0
T	P	B	0	0	38	5	<1	1	0	0	5	5	2	1
T	L+E	B	0	0	38	1	<1	0	0	0	1	1	<1	1
T	P+C	B	0	0	30	4	<1	1	0	0	2	1	<1	1
							Expt. II						Expt. IV	
-	-	B	48	29	45	9	7	3	38	28	29	12	12	2
-	L	B	0	0	19	2	1	0	0	0	8	1	<1	0
-	P	B	4	4	24	2	2	2	3	2	17	6	4	2
T	-	B	0	0	8	2	<1	1	1	1	9	5	2	1
-	-	B+E	28	1	37	2	1	1	44	9	43	14	11	1
-	L	B+E	0	0	25	0	0	0	0	0	7	2	1	0
-	P	B+E	2	0	24	1	<1	1	1	1	16	10	6	1
T	-	B+E	2	0	14	2	<1	0	2	0	13	5	2	0

Key:
L - lenacil
P - propachlor
T - trifluralin
C - chlorthal dimethyl
B - phenmedipham
E - ethofumesate
a - before post-em. treatment
b - after post-em. treatment

* all weeds then hand-hoed

** weeds removed whenever mean ground cover per treatment reached 10%

of the pre- and post-planting herbicides were greater than in 1978, but the ranking order of treatments remained similar to that of the previous year (Table 3). Post-emergence treatments were not as effective in removing surviving weeds as they had been in 1978 and, other than in controlling P. annua, the phenmedipham/ethofumesate mixture performed little better than phenmedipham alone. Species resistant to completed programmes included P. aviculare, Urtica urens, V. arvensis, and Veronica spp., while post-emergence treatment by itself also failed to control Matricaria spp.

Ground cover scores on 9 July (Table 3) show the high level of weed control obtained with all herbicide programmes. Two supplementary weedings were required on plots treated only with phenmedipham or with this herbicide preceded by propachlor. Other programmes required only one further weeding, or none, before late December. As in 1978, the phenmedipham/ethofumesate mixture enhanced persistence in comparison with treatments involving phenmedipham alone. The main species germinating in late summer and autumn were P. annua, V. arvensis, U. urens, S. media and S. vulgaris.

DISCUSSION

The choice of a suitable herbicide programme for strawberries requires consideration of three main factors - crop safety, efficacy and cost. All the herbicides used in these experiments have proved safe to the crop when evaluated individually at SHRI and other centres in the United Kingdom (Clay, 1978; Clay, Lawson & Stott, 1974; Clay, Rutherford & Wiseman, 1974; Lawson & Wiseman, 1974, 1978). Less information is available about their safety when used in tank-mixtures and/or sequences. Given the abnormally high rainfall which occurred shortly after the application of post-planting herbicides in 1978, the degree of crop injury was less than expected, although useful information was gained on relative tolerance of the crop to different herbicides alone and in programmes. The greater sensitivity to propachlor than to lenacil in both experiments in 1978 is not in agreement with results in our earlier field experiments (Lawson & Wiseman, 1978) or in sand culture tests (Clay, 1980). Lower tolerance to propachlor/chlorthal dimethyl than to propachlor alone in Expt. III in 1979 was unexpected, since this did not occur in 1978 despite very heavy rainfall after treatment, and since chlorthal dimethyl is normally very safe in strawberries (Clay et al, 1974). Both these situations merit further examination, although the effects were eventually outgrown. Post-emergence treatment with the phenmedipham/ethofumesate mixture caused some leaf malformation, but no prolonged adverse effect in either year. Clay (personal communication) has found that Cambridge Favourite is generally tolerant of phenmedipham/ethofumesate mixtures, but that several other cultivars are more susceptible. The lenacil/ethofumesate mixture checked crop growth in both years and was involved in the only instance of a statistically significant adverse interaction between sequential components of programmes. This indicated that pre-planting treatment with trifluralin may have rendered the crop more sensitive to lenacil/ethofumesate applied post-planting. Otherwise, despite the fact that individual components of programmes checked early growth in several experiments, there was no evidence that sequential application of herbicides increased the vulnerability of the crop to herbicide injury. Lenacil was the safest post-planting constituent of any programme. This may be an important consideration in years when soil or weather conditions immediately after planting are known to be conducive to crop injury, particularly if a post-emergence herbicide can be relied on to control lenacil-resistant weeds. The lenacil /ethofumesate mixture was not as safe and it may be worth considering alternative mixtures containing less ethofumesate and more lenacil.

Under the conditions of these experiments all herbicide programmes gave satisfactory control of the spring flush of weeds, but in almost all cases it required the combined action of sequential treatments to achieve this result. No individual programme required more than a minimal amount of hand-hoeing in early summer to make the plots weed-free. There was relatively little to choose between programmes at that stage, although those involving propachlor were usually weedier than the rest. This applied also in terms of the persistence of weed control thereafter. Programmes involving propachlor followed by phenmedipham had little residual effect, unless augmented by chlorthal dimethyl or trifluralin. Ethofumesate applied post-emergence with phenmedipham had a residual effect, especially on P. annua, which considerably improved persistence of weed control into the autumn. This mixture could be of considerable value in crops where pre- or post-planting herbicides have failed to perform adequately.

In three of the four experiments, plots treated with the standard lenacil and phenmedipham sequence required no further weeding before the end of the year. Several other programmes kept plots virtually weed-free well into the autumn, the required degree of weed control. In commercial practice, however, a number of the programmes evaluated (including the standard) will not be effective or even feasible in all situations. Soils may be too stony for incorporation of trifluralin; they may be too dry after planting for effective performance by surface-applied residual herbicides, and certain soil types in any case preclude the use of several of these herbicides; the weather conditions under which phenmedipham may be applied are somewhat restricted; crop tolerance may have to be given precedence over weed control performance; weed species and density vary from site to site. It is therefore important that sufficient flexibility is available to the grower to enable him to adapt to local and seasonal conditions. The programmes used in these experiments, plus other obvious permutations of the same components, offer a wide range of options.

In terms of chemical cost, there was little difference between lenacil followed by phenmedipham and the use of either component in mixture with ethofumesate. The cost range of other programmes which gave good initial weed control and effective persistence was from 30% less to 30% more than that of lenacil followed by phenmedipham. Considering the value of the strawberry crop and the importance of good establishment in the first year, this is not a sufficiently wide range to exclude a programme on the basis of cost.

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STRAWBERRY RUNNER CONTROL WITH DINOSEB-IN-OIL

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Summary Dinoseb-in-oil was evaluated against paraquat for the control of runners in strawberry alleys. The standard rate of paraquat (1.12 kg a.i./ha) and dinoseb-in-oil at 2.50 - 5.00 kg a.i./ha averaged more than 95% desiccation of treated vegetation over a very wide range of conditions. Dinoseb-in-oil gave more rapid desiccation than paraquat, unless wet weather occurred following application. Speed of desiccation was greater in warm than in cold weather and at higher than at lower rates of application. However, there was relatively little effect of weather on the recovery of treated plants from rates of 2.50 kg a.i./ha and above. Paraquat gave much longer-lasting control of runner plants than did dinoseb-in-oil, but the latter showed no evidence of damaging strawberry plants in the crop row by translocation from treated runners. Effective application of dinoseb-in-oil, using conventional fan jets, required 500 to 1000 l water/sprayed ha, the higher volume occasionally giving better results. Dinoseb-in-oil offers an effective, less phytotoxic and cheaper alternative to paraquat for runner desiccation, but the need for more frequent treatment makes chemical costs comparable. Additional application costs with dinoseb-in-oil may be offset by those incurred in protecting the crop row from translocation by paraquat.

INTRODUCTION

Paraquat has been used to control strawberry runners in the alleys between rows since the early 1960s. The treatment is generally very effective, but there is a risk of damage to the crop in the row as a result of spray drift or of translocation from treated runners. By using special application equipment, and discing on both sides of the crop row to sever the runners from the parent plants, these problems can be avoided (Fryer & Makepeace, 1978). In practice, many growers omit the discing operation and hope that injury will not occur. Regional ADAS reports, however, indicate that considerable and occasionally very severe injury by translocation has occurred in recent years, following the use of paraquat without discing. Damage has been especially common after late autumn application, after a period of drought, or when severe winter weather followed autumn treatment (A. G. Jones, personal communication).

Dinoseb-in-oil has been widely used for many years as a pre-harvest desiccant and has recently had its recommendations extended to include the control of unwanted vegetation in both raspberry and hop (MAFF, 1980). Dinoseb acts primarily as a contact foliar herbicide and translocation within the plant is negligible (Fryer & Makepeace, 1978). The use of the oil formulation as an alternative to paraquat was examined in a series of field experiments at SHRI.

METHOD AND MATERIALS

Eight experiments were carried out between 1978 and 1980 on established plantations of cv. Cambridge Favourite grown in matted rows 60 cm wide. Experimental plots were based on single alleys, 6.75 m long by 30 cm wide, between two matted rows. All treatments were replicated 3 or 4 times in randomised blocks. Runners were allowed to grow and root freely in the alleys during the summer months, and runner connections between row and alley were not severed before spray application. Drift to the matted rows was prevented by means of weighted plastic shields placed over the crop row immediately before treatment 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. Other than in experiments to test the effect of water volume, application was made at 2.76 bar pressure in 1000 l water/sprayed ha. Volumes of 500 l/ha were applied at 2.42 bar. A 25% w/v formulation of dinoseb-in-oil (Marks DNBP in Oil 25) was applied at rates of from 1.25 to 5.00 kg a.i./sprayed ha. Rates and water volumes used in individual experiments are shown in Tables 1-4. Paraquat (Gramoxone), applied at 1.12 kg a.i. in 1000 l water/sprayed ha, and an untreated control, were included in all experiments. Timing of treatment ranged from early autumn to spring. All plots were treated once only, in calm, dry weather; note was taken of the weather conditions for several days following application. After treatment, plots were scored regularly for efficacy of desiccation (0 = unaffected, 10 = 100% foliage kill) until after the maximum effect had been reached. When treated plots began to show evidence of recovery, counts were made of numbers of new leaves or of live runner plants per unit area. Observations were also made on any spread of herbicide effects into the adjacent matted rows.

RESULTS

Speed and efficiency of desiccation

Results of applying dinoseb-in-oil at rates of between 1.25 and 3.75 kg a.i./ha are summarised in Table 1. The latter rate gave virtually complete desiccation in all experiments, and data for higher rates (4.38 and 5.00 kg a.i./ha) are therefore not presented. Paraquat at the standard rate always gave excellent desiccation, but was generally slower to act than dinoseb-in-oil, unless wet weather followed spray application, as in Expts. VI and VII. Speed of desiccation with dinoseb-in-oil was greater in warm weather than in cold, and at higher than at lower dosages. Maximum scores achieved were, however, relatively little affected by weather, especially at the higher dosages applied. All rates of dinoseb-in-oil except 1.25 kg a.i./ha gave over 90% kill of treated vegetation. The dosage needed to equal the performance of paraquat was between 2.50 and 3.13 kg a.i./ha. No further improvement was obtained at 3.75 kg a.i./ha.

Varying the water volumes in the range 500 - 2000 l/sprayed ha had relatively little effect on speed of action or final desiccation score, compared with changing the dosage of dinoseb-in-oil (Table 2). 2000 l/ha appeared unnecessarily high in Expt. II; 500 and 1000 l/ha were equally effective in Expts. III and VIII and gave a significantly better maximum effect than 1500 l/ha in the latter experiment. In Expt. VII, desiccation with 1000 l/ha was better overall than with 500 l/ha or 1500 l/ha, but the differences decreased with higher dosage. Comparison of one concentration (2.5 g a.i./l of water) applied at 500, 1000 and 1500 l/sprayed ha in Expts. II and VII showed increasing efficiency of desiccation up to the highest rate of application (3.75 kg in 1500 l/ha).

Recovery of sprayed runner plants

Paraquat had a major effect on runner plants, achieving 88 - 95% reduction in plant numbers compared with the untreated control (Table 3). Those which did survive

Table 1

Effect of desiccant treatment on foliage

Treatment kg a.i /ha	Timing of score	I Dry, very warm	II Dry, warm	III Dry, mild	IV Dry, cold	V Dry, frosty	VI Very wet, cool	VII Wet, cold	Mean for all expts.
		Experiment, and weather following treatment							
		Desiccation scores (0 - 10)							
Dinoseb									
1.25	a	-	4.8	-	-	-	-	0.5	7.40 (2)
	b	-	8.3	-	-	-	-	6.5	
1.88	a	9.7	-	4.7	2.0	-	2.2	-	9.35 (4)
	b	9.7	-	9.3	9.2	-	9.2	-	
2.50	a	9.6	6.8	6.3	2.7	0.8	4.7	1.3	9.61 (7)
	b	9.7	9.1	9.8	9.8	9.2	9.9	9.8	
3.13	a	9.9	-	7.7	6.5	1.0	5.3	-	9.96 (5)
	b	10.0	-	10.0	10.0	9.8	10.0	-	
3.75	a	9.8	8.9	8.0	6.8	1.0	4.5	3.3	9.97 (7)
	b	10.0	10.0	10.0	10.0	9.8	10.0	10.0	
Paraquat									
1.12	a	9.3	4.0	3.0	3.0	0.5	8.0	5.3	9.81 (7)
	b	9.7	9.3	10.0	10.0	9.7	10.0	10.0	
S.E. mean ±	a	0.12	0.51	0.48	0.44	0.12	0.54	0.34	
	b	0.58	0.24	0.20	0.10	0.12	0.08	0.58	

Key: Desiccation scores
0 = unaffected
10 = 100% foliage kill
a = scored after approx. one week
b = maximum score achieved

Table 2

Effect of dosage and water volume on foliage

Treatment kg a.i./ha	Water volume l/ha	Timing of score	Experiment II	VII	III	VIII
Dinoseb			Desiccation scores (0 - 10)			
1.25	500	a	4.8	0.7	-	-
		b	8.3	4.7	-	-
	1000	a	-	0.5	-	-
		b	-	6.5	-	-
	1500	a	-	0.5	-	-
		b	-	4.8	-	-
	2000	a	1.0	-	-	-
		b	7.4	-	-	-
2.50	500	a	-	1.5	6.3	-
		b	-	8.5	9.8	-
	1000	a	6.8	1.3	5.3	-
		b	9.1	9.8	9.7	-
	1500	a	-	0.8	-	-
		b	-	9.0	-	-
	2000	a	4.1	-	-	-
		b	9.3	-	-	-
3.75	500	a	-	2.0	8.0	1.5
		b	-	9.3	9.8	10.0
	1000	a	-	3.3	8.0	1.3
		b	-	10.0	10.0	10.0
	1500	a	8.9	2.7	-	1.2
		b	10.0	10.0	-	9.3
	2000	a	8.1	-	-	-
		b	9.9	-	-	-
S.E. mean ±		a	0.51	0.34	0.48	0.21
		b	0.24	0.58	0.20	0.22
Sig. of effect of volume		a	-	NS	NS	-
		b	-	*	NS	-

* Effect significant at the 5% level NS - Not significant

\- Not applicable

Key: Desiccation scores

0 = unaffected

10 = 100% foliage kill

a = scored after approx. one week

b = maximum score achieved

Table 3

Effect of desiccant treatment on recovery of sprayed runner plants

Treatment kg a.i./ha	Experiment I	Experiment IV	Experiment VI
Dinoseb	Number of live runner plants/m^2		
1.88	94	112	131
2.50	112	110	113
3.13	90	83	96
3.75	87	101	108
Paraquat			
1.12	21	12	6
Untreated control	138	146	114
S.E. mean ±	10.8	16.1	7.7
Sig. of effect			
Untreated control v all dinoseb	**	*	NS

*, ** Effect significant at the 5% or 1% level respectively

NS Not significant

produced leaves with chlorotic symptoms typical of the effect of the herbicide, and leaf counts (Table 4) therefore underestimate the extent of the injury to treated plants. Paraquat was also translocated 2 - 5 cm into the crop row, producing an erratic edge to the alley, compared with the unchanged straight edge maintained on plots treated with dinoseb. In addition, observations made in spring 1979 and 1980 on plots treated the previous late autumn (Expts. IV, VI and VII) showed that paraquat had, in places, been translocated distally along runner connections to and had killed secondary runner plants rooted in the matted rows adjacent to the treated alley.

Dinoseb-in-oil showed no evidence of movement outside the sprayed area. Plant numbers in the alleys were reduced by 31% overall in two experiments, but there was no useful effect in a third (Table 3), possibly because of very wet weather following application. New leaves showed no herbicide symptoms and, other than in Expt. II, were much more numerous than on plots treated with paraquat (Table 4). There was no clear evidence of an effect of rate of application of dinoseb-in-oil on plant survival at the four rates applied in Expts. I, IV and VI (Table 3). However, in three other experiments (Table 4), there were significant dose responses. A rate of 1.25 kg a.i./ha resulted in greater recovery than occurred at 2.50 kg a.i./ha, which in turn was less effective than higher rates of application. These experiments also showed a response to water volume, but no interaction between volume and dosage. Application at 1000 l/ha resulted in less regrowth than at 500 l/ha in Expts. II and III, with 1500 l/ha showing no advantage over 1000 l/ha in Expt. III. Finally,

Table 4

Effect of dosage and water volume on recovery of sprayed runner plants

Treatment kg a.i./ha	Water volume l/ha	Experiment II	III	VII
Dinoseb		Number of new leaves/m^2		
1.25	500	-	98	88
	1000	-	101	-
	1500	-	91	-
	2000	-	-	92
1.88	500	33	-	-
	1000	31	-	-
2.50	500	37	104	-
	1000	26	70	63
	1500	-	61	-
	2000	-	-	59
3.13	500	26	-	-
	1000	14	-	-
3.75	500	22	76	-
	1000	11	51	-
	1500	-	62	53
	2000	-	-	39
Paraquat	1000	15	17	15
S.E. mean ±		3.0	10.0	9.5
Sig. of effects of dinoseb				
Dosage		***	**	-
Volume		**	*	-
Interaction		NS	NS	-

*, **, *** Effect significant at the 5%, 1% or 0.1% level respectively

NS Not significant - Not applicable

2000 l/ha showed no advantage over lower volumes in Expt. VII Applying a concentration of 2.5 g a.i./l of water at 500, 1000 and 1500 l/sprayed ha resulted in less leaf recovery with increasing dosage in both Expts III and VII.

In general, recovery after autumn or winter treatment was very much slower than that after spring treatment, regardless of the rate or volume of application of dinoseb-in-oil.

DISCUSSION

Dinoseb-in-oil was much less effective than paraquat in killing runner plants in the alley. It would therefore not be an attractive alternative to growers prepared to risk translocation of paraquat to the crop row or to incur the additional cost of discing along row edges. On the other hand, dinoseb-in-oil gave equally efficient and more rapid desiccation of runner foliage and did kill a proportion of the runner plants in some experiments, presumably because of spray lodging in crown axils. There was, however, no evidence of movement outside the treated alley. Both the advantages and the disadvantages of the two herbicides depended therefore on relative differences in translocation.

In terms of effectiveness of desiccation of treated foliage, the rate of dinoseb-in-oil needed to give results equivalent to those obtained with the standard rate of paraquat lay between 2.50 and 3.13 kg a.i./ha. At 2.50 kg a.i./ha, the mean score over seven experiments was 96% kill of treated foliage, compared with 98% for paraquat, and there appears little point in further increasing the dosage of dinoseb-in-oil to achieve 100% desiccation. Data on the recovery of runner plants following desiccation also suggest that little extra benefit was obtained from increasing the dosage above 2.50 kg a.i./ha. This is the rate generally recommended for control of annual weeds (Fryer & Makepeace, 1978) and would seem to be a sensible rate to suggest for the control both of runners and of weeds in strawberry alleys. At current prices (September 1980), 1.12 kg paraquat costs some 50% more than 2.50 kg dinoseb-in-oil. Against this must be set the need for more frequent repetition of the treatment with dinoseb-in-oil Three treatments with the latter would cost the same for chemicals as the two normally recommended for paraquat (Fryer & Makepeace, 1978). The cost of the third application of dinoseb-in-oil may be offset against the cost of discing before applying paraquat. In economic terms, therefore, there may be little difference between the herbicides, provided that three applications of dinoseb-in-oil are sufficient. This requires further examination under commercial conditions.

Experiments on water volume using conventional fan jets suggested that for a rate of 2.50 kg a.i./ha a volume of 1000 l/ha was the most consistently effective. Larger volumes appeared unnecessary, while 500 l/ha sometimes gave slightly poorer desiccation and greater recovery, presumably due to insufficient coverage. The major objective, as with potato haulm desiccation and cane vigour control in raspberries, must be to ensure complete coverage of the strawberry runner foliage with an adequate concentration of dinoseb-in-oil. The volume required to achieve this will vary depending on the mass of vegetation to be treated, but was between 500 and 1000 l/ha in these experiments. Other data (not presented) indicate that a volume of 250 l water/ha is insufficient to give adequate coverage of runner foliage with conventional fan jets. Further work is needed on the performance of dinoseb-in-oil with other methods of application, such as the dribble bar, Vibrojet or Warnock sprayer. Application of a single concentration (2.5 g a.i./l of water) at different volumes/ha gave inadequate desiccation at low volume and unnecessarily high dosage of dinoseb-in-oil at high volume. It therefore appears preferable to apply a fixed dosage of dinoseb-in-oil/ha, with the spray volume varying according to foliage density and method of application.

The possibility of using dinoseb-in-oil as an alternative to mechanical cutting for cultivars which respond to defoliation after fruit harvest was examined at SHRI by Mason & Stephens (1965). They achieved acceptable levels of defoliation and an increase in the initiation of inflorescences, but fruit yield in the following summer was consistently lower than that on plots defoliated mechanically. They attributed this to slower recovery of sprayed plants and to the development of fewer branch crowns during autumn than on plants defoliated mechanically. Our own results showed that up to 31% of treated runner plants did not recover. The use of dinoseb-in-oil in strawberry plantations must therefore be restricted to the control of runners in the alleys. For this purpose it offers a useful alternative to paraquat.

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