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NEW HERBICIDES FOR SPRING-PLANTED STRAWBERRIES

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Summary Spring-planted strawberries were treated shortly after planting with four herbicides which were compared with simazine and lenacil as standards. Each herbicide was applied at three rates. Lenacil at up to 6.7 kg a.i./ha had no adverse effect on the crop; nor did simazine at 1.1 kg a.i./ha, but at twice and three times this rate it caused severe injury and plant death. Pendimethalin, propachlor and ethofumesate caused no consistent crop injury, even at three times the suggested commercial dosage. A trietazine/simazine mixture had no greater safety margin than simazine alone, but gave much better control of *Polygonum aviculare*. Propachlor was more effective on *Viola arvensis* and *P. aviculare* than lenacil, while ethofumesate controlled *Stellaria media* better than either lenacil or simazine, but the outstanding herbicide was pendimethalin, particularly under dry soil conditions. All of these herbicides may find a useful place in programmes of weed control for the strawberry crop, although trietazine/simazine may have to be restricted to situations in which simazine is normally safe to use.

INTRODUCTION

Spring-planted strawberries are highly vulnerable to competition from spring-germinating weeds during establishment (Lawson & Wiseman, 1976). Particular attention has therefore been paid in recent years at SHRI to the evaluation of herbicides for use in newly-planted crops, (Lawson & Wiseman, 1974; Clay, Lawson & Stott, 1974; Clay, Rutherford & Wiseman, 1974). The experiments reported here were carried out as part of a joint programme of evaluation by the ARC Fruit Weed Control Group. A trietazine/simazine mixture and ethofumesate appeared promising in early evaluation experiments (Clay *et al*, 1974); pendimethalin and propachlor were included following promising crop tolerance in preliminary trials at the ARC Weed Research Organisation (Clay & Davison, 1978). These herbicides were compared with the standard herbicides - simazine and lenacil.

MATERIALS AND METHODS

Two experiments were carried out (one each in 1976 and 1977) at Invergowrie on sandy clay 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 experiments were laid out as randomised blocks with three replicates of six herbicide treatments each applied at three dosages. There were also three untreated plots per replicate.

Herbicide application was made by Oxford Precision Sprayer in 600 l water/ha to a 90 cm band centred on the crop row. Application rates and formulations used were as follows:-

Herbicide	Rate kg a.i./ha			Formulation
	I	II	III	
Lenacil	2.2	4.5	6.7	80% w.p.
Simazine	1.1	2.2	3.4	50% w.p.
Trietazine/simazine	1.7	3.4	5.0	49% + 7% w.p.
Pendimethalin	1.7	3.4	5.1	30% e.c.
Propachlor	4.5	9.0	13.5	65% w.p.
Ethofumesate	1.1	2.2	3.4	20% e.c.

Plots were scored regularly for percentage ground cover by weeds during April and May. Weed counts were taken and all weeds removed by hand-hoeing well before the onset of shading of crop foliage by weeds on untreated plots. All plots were thereafter maintained weed-free. Strawberry plants were allowed to fruit in both experiments; a single harvest of ripe and green berries was taken, when the first fruits were turning red. In the first experiment runners were trained into the rows and recorded only at the end of the growing season, while in the second experiment they were removed and recorded twice during the summer. A destructive crown count was taken in late autumn.

RESULTS

Experiment I, 1976

The weather was wet for a long spell until a few days before planting on 5 April and then sunny and dry until spray application on 7 April. There was slight rain within the next few days, followed by three weeks of dry weather. May had above average and the summer months had below average rainfall.

Rainfall mm (± deviation from average)

March	April	May	June	July	August
71(+28)	23(-19)	82(+23)	16(-35)	51(-16)	13(-60)

Weed control

Weeds emerged in very large numbers in late April. Percentage ground cover by weeds on untreated plots was 10% by 10 May. Only pendimethalin, propachlor and trietazine/simazine delayed the spread of weeds satisfactorily at the single rate, pendimethalin being by far the best. Increasing the dose improved the performance of trietazine/simazine and propachlor but, even at three times the recommended dosage, weed cover on plots treated with ethofumesate, lenacil or simazine was not appreciably less than that on untreated plots by the

Table 1

Weed records

Treatment	Expt. I (1976) Weed count/m^2 10 May				Expt. II (1977) Weed count/m^2 3 June			
	Total	P.av.	V.a.	S.m.	Total	P.av.	V.a.	P.an.
Untreated	691	346	201	55	316	123	51	50
S.E. mean ±	65.2	36.6	35.7	7.6	29.4	21.0	15.1	8.1
Trietazine/simazine I	567	248	266	18*	22***	14*	4	0**
II	352*	172*	154	7**	11***	4**	0	0**
III	258**	126**	126	0***	4***	0**	0	0**
Pendimethalin I	718	341	330	25	86***	11*	7	57
II	445	154*	251	32	61***	0**	7	43
III	388*	190*	183	11**	22***	0**	3	11*
Propachlor I	377*	215	154	4**	122**	32*	57	0**
II	240**	176*	57	3**	50***	18*	29	0**
III	133***	79***	54*	0***	61***	7**	40	0**
Ethofumesate I	736	373	298	0***	187*	43	115*	0**
II	592	326	240	0***	201	68	61	7*
III	556	291	215	3**	122**	57	29	0**
Lenacil I	779	431	276	25	104***	14*	68	7*
II	488	222	190	32	75***	40	29	0**
III	667	294	262	79	161*	22*	136*	3*
Simazine I	775	416	298	25	83***	72	11	0**
II	850	481	330	29	68***	57	7	0**
III	574	355	161	22*	40***	25*	7	0**
S.E. mean ±	112.9	63.3	61.9	13.2	50.9	36.3	26.2	14.0

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

Weed key - P.av. - Polygonum aviculare
V.a. - Viola arvensis
S.m. - Stellaria media
P.an. - Poa annua

Table 2

<u>Expt. I - Crop records/live plant</u>

Treatment		8 June Mean height (cm)	8 June Mean spread (cm)	29 June Mean wt. fruit(g)	14 October Mean no. stolons	14 October Mean wt.(g) stolon	14 October Mean no. crowns	14 October No. live plants/ plot
Untreated		9.5	14.8	12.7	12.8	35.7	2.7	13.3
S.E. mean ±		0.45	0.52	1.15	0.66	2.33	0.16	0.59
Trietazine/ simazine	I	8.7	14.6	9.8	12.8	36.4	2.7	13.7
	II	7.7*	13.3	7.2*	11.8	42.0	2.8	10.7*
	III	7.1**	12.6*	5.7**	10.4	42.4	2.2	6.3***
Pendimeth-alin	I	8.9	14.8	15.5	14.0	34.3	3.1	13.3
	II	8.0	14.2	15.0	12.0	35.8	2.5	12.7
	III	7.2*	13.8	10.5	12.2	40.7	2.1	13.3
Propachlor	I	8.7	14.4	15.8	12.0	35.8	2.4	13.7
	II	7.8	13.6	9.5	12.8	34.3	2.8	9.7**
	III	7.6*	13.6	14.1	10.8	39.1	2.0*	12.0
Ethofumesate	I	9.5	14.9	13.4	11.6	36.4	2.4	13.7
	II	9.9	14.9	16.4	12.4	40.2	2.6	12.3
	III	8.4	14.5	9.6	12.8	38.8	2.7	13.0
Lenacil	I	8.5	14.7	9.1	13.2	44.8	2.9	14.0
	II	8.8	14.9	12.6	12.4	35.4	2.8	13.0
	III	8.9	14.5	11.9	14.8	30.9	3.5	13.3
Simazine	I	9.3	15.5	11.7	12.6	33.1	2.6	13.7
	II	7.5*	11.6**	7.1*	11.4	36.1	2.6	9.0***
	III	5.9***	10.6***	5.4**	7.6***	36.8	1.8***	7.0***
S.E. mean ±		0.78	0.90	1.99	1.14	4.03	0.28	1.02

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

time of weed removal.

Weed counts on 10 May show the predominance of Polygonum aviculare and Viola arvensis in this experiment and the apparent failure of any of the herbicide treatments to control them satisfactorily (Table 1). However, weed seedling counts underestimate the effects of pendimethalin. This herbicide stunted surviving weeds very severely; those which emerged remaining at the cotyledon stage until the date of weed removal. Of the other herbicides, propachlor gave best results particularly at higher rates. Lenacil and simazine at any dose failed to give effective control of Stellaria media, which was virtually eliminated by ethofumesate. The latter herbicide and lenacil were also ineffective in control of Myosotis arvensis.

Crop tolerance

First signs of phytotoxicity were noted on 26 April on plots treated with simazine and trietazine/simazine. At that time the plants were suffering from water stress. Heavy showers on 3 May helped plant growth and several weeks of wet weather followed. Both herbicides caused temporary yellowing of leaves, but had no permanent adverse effects on the crop at the single rate. Higher rates resulted in death of some plants in June, and a growth check to the survivors (Table 2); fruit yields were also reduced. However, by mid October, surviving plants showed considerable recovery, apart from those treated with the highest rate of simazine. Most other herbicide treatments had little or no adverse effect on the crop even at three times the recommended rate. The significant level of plant death recorded on plots treated with the double rate of propachlor did not occur at the treble rate. However, there was evidence of a reduction in crown numbers/plant at the latter rate.

Experiment II, 1977

Soil and air temperatures were low in the week prior to planting on 7 April. Light rain fell on several days thereafter; it was then windy and dry for several weeks. Spray application was made on 18 April. May rainfall was well below average.

Rainfall mm (± deviation from average)

March	April	May	June	July	August
56(+13)	20(-22)	27(-32)	54(+3)	37(-29)	63(-10)

Weed control

Weeds emerged within a few days after herbicide treatment and ground cover reached 14% on untreated plots by 27 May. All single rates of herbicide reduced the rate of increase of weed cover, pendimethalin and trietazine/simazine giving best results. Increasing the dose improved the performance of propachlor and simazine, but not that of ethofumesate or lenacil. Weed counts on 3 June again showed the predominance of P. aviculare, although V. arvensis and Poa annua were present in substantial numbers on untreated plots (Table 1). Pendimethalin and trietazine/simazine gave the best overall control, the former again stunting surviving broad-leaved weeds until the date of weed removal. However, it was the least effective herbicide in reducing numbers of P. annua and did not stunt plants of this species

Table 3

Expt. II - Crop records/live plant

Treatment	24 June Mean height (cm)	24 June Mean spread (cm)	10 August Mean wt. fruit(g)	10 August Mean no. stolons	10 August Mean wt.(g) /stolon	3 November Mean no. crowns	3 November No. live plants/ plot
Untreated	12.3	24.2	22.6	7.9	8.9	4.4	14.7
S.E. mean ±	0.32	0.96	1.16	0.66	0.77	0.36	0.33
Trietazine/ simazine I	10.8*	24.4	20.6	9.9	6.5	6.2	14.0
II	9.8***	20.2*	13.7***	6.7	9.4	4.4	12.3**
III	7.7***	12.1***	4.7***	3.3**	6.3	3.5	7.0***
Pendimeth-alin I	10.4**	21.4	19.0	7.5	8.5	5.1	13.7
II	11.1	24.7	20.3	9.7	10.0	5.1	14.7
III	10.5*	21.6	17.8*	8.3	9.9	4.7	14.0
Propachlor I	11.6	26.8	28.7*	10.0	12.9	5.4	14.7
II	11.3	24.0	23.9	8.0	10.2	4.9	15.0
III	11.5	26.2	26.6	10.1	11.2	5.9	14.7
Ethofumesate I	11.4	23.4	21.0	8.0	9.2	4.1	14.7
II	11.2	23.0	21.0	7.5	8.5	4.2	15.0
III	11.2	25.5	25.1	9.2	11.7	4.5	15.0
Lenacil I	10.8*	24.1	20.1	9.6	9.8	5.3	14.7
II	11.9	25.3	25.6	11.4*	11.0	5.9	14.0
III	11.7	27.5	25.8	10.8*	11.5	5.4	14.7
Simazine I	11.7	23.9	20.4	8.4	10.6	4.9	14.3
II	9.9***	20.0*	14.3***	6.7	8.5	4.0	12.0***
III	8.2***	15.7***	8.0***	6.2	6.7	4.3	10.3***
S.E. mean ±	0.55	1.67	2.01	1.14	1.33	0.62	0.58

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

to the same extent. P. aviculare was the main surviving species on plots treated with trietazine/simazine and simazine, but V. arvensis was of more importance on plots treated with propachlor, ethofumesate and lenacil.

Crop tolerance

First signs of phytotoxicity were noted on 16 May on plots treated with simazine and trietazine/simazine. Both herbicides again caused leaf yellowing (which was soon outgrown) at the single rate, but killed plants and reduced the size of the survivors and their production of fruit at higher rates (Table 3). However, by mid October, surviving plants had to a large extent recovered. Pendimethalin checked plant growth slightly in May and June, and fruit yield was reduced on plots treated at the treble rate but there were no adverse effects recorded thereafter. None of the other herbicides had any consistent adverse effects on the crop, even at the treble rate.

DISCUSSION

Three of the herbicides evaluated in these experiments are already widely used in arable crops in the United Kingdom - propachlor in brassicae, ethofumesate in sugar beet and trietazine/simazine in peas (MAFF 1978). Propachlor gave better weed control than lenacil in both experiments and will be a useful addition to the herbicide range for spring-planted (and established) strawberries, if an adequate safety margin is confirmed. Clay (1978a) reports no injury to young plants at twice the proposed commercial rate. Ethofumesate was no better than lenacil in controlling P. aviculare or V. arvensis, but its apparent safety to the crop in this and other experiments (Clay, Rutherford & Wiseman, 1974) permits consideration of its mixture with lenacil, as for sugar beet, to improve overall performance on a wider range of species (Griffiths, 1976).

Trietazine/simazine and simazine caused damage to a similar extent, rate for rate, in both years. The single rate of simazine and three times the normal rate of lenacil had no adverse effect on crop establishment and it may be assumed that spring weather conditions in 1976 and 1977 at SHRI were not conducive to above-average herbicide injury to the crop. However, the risk of damage with simazine has always been considered too high for its use to be recommended commercially as a post-planting treatment. The results indicate that trietazine/simazine merits similar conclusions. Ellis (1973), Rath and O'Callaghan (1976) and Clay (1978b) have also reported variable degrees of injury to autumn and spring-planted crops. It therefore appears unlikely that this herbicide can be used in the young crop. However, it has proved safe in a number of experiments on established crops (Ellis, 1973; Clay, Rutherford & Wiseman, 1974) and its considerable advantage over simazine in weed control efficacy suggests that it may be a useful alternative in crop situations and at times of year when it is normally safe to use the latter herbicide. In neither year did any of the commercially available herbicides give the level of weed control which would have avoided the need for soil cultivation in early summer. The very dense populations of weeds in 1976 posed an unusually difficult problem. In these circumstances the effect of pendimethalin on broad-leaved weeds was of particular interest. Clay et al (1974) also reported appreciably better weed control than with lenacil in dry conditions. Pendimethalin appears to be generally safe to use in young or established plantations, despite evidence of temporary stunting of strawberry foliage (Clay et al, 1974; Clay, 1978a) but more information on tolerance over a wider range of crop and environmental situations is desirable.

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THE RESPONSE OF STRAWBERRIES TO PROPACHLOR, PENDIMETHALIN AND TRIFLURALIN USED ALONE, IN MIXTURE OR SEQUENTIALLY

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Summary Propachlor at 4.5 and 9.0 kg/ha was safe on newly-planted strawberries (cv. Gorella) both as a pre-planting incorporated treatment or applied post-planting. The lower rate applied as a mixture with trifluralin (1.1 kg/ha) pre-planting or applied post-planting after trifluralin treatment was also safe. Propachlor applied at 4.5 and 9.0 kg/ha in spring had no adverse effect on 1 and 2 year-old crops.

Pendimethalin at 1.5 and 3.0 kg/ha alone or mixed with propachlor at 4.5 and 9.0 kg/ha caused stunting of newly-planted crops but no adverse effect on subsequent growth. When applied to a 1 year-old crop in spring 1977 pendimethalin alone or in mixture with propachlor caused temporary leaf stunting but fruit yield was 20% higher than with lenacil (2 kg/ha). Similar treatments on 1 and 2 year-old crops in spring 1978 had no effect on total yield but significantly increased the amount of fruit picked early in the harvest period.

INTRODUCTION

Trifluralin is widely used in the U.K. for the control of annual weeds in newly-planted strawberries; it is usually followed by a post-planting residual herbicide It is more effective in dry conditions than lenacil or chloroxuron and it controls some weed species resistant to these herbicides (Bryant and Farrant, 1974; Lawson and Wiseman, 1974). Two disadvantages with its use are the need for pre-planting incorporation of the herbicide within 30 minutes of spraying and the necessity of using a further residual herbicide treatment immediately after planting to control resistant weeds. To try and overcome these disadvantages experiments were carried out at WRO to test the tolerance of strawberries to propachlor and pendimethalin. Propachlor is widely used in vegetable crops post-planting following pre-planting trifluralin treatment (Makepeace, 1976). It has a complementary weed spectrum to trifluralin and is cheaper than the alternative post-planting herbicides. Pendimethalin was tested as a possible alternative to trifluralin. It controls a similar range of weed species but does not require soil incorporation. It is widely used in USA and is under development in the U.K. for use in winter barley (Winfield et al., 1978).

The potential tolerance of strawberries to pendimethalin and propachlor was found in pot experiments at WRO involving tests of root activity in sand culture (Clay and Davison, 1978). Preliminary field trials confirmed the tolerance of newly-planted and established strawberries to pendimethalin (Clay et al., 1974). More recently experiments co-ordinated by the ARC Fruit Weed Control Group have been carried out at a number of centres in the U.K. to confirm the safety of these treatments (Loughgall, 1977; Lawson and Wiseman, 1978). In the work at WRO reported here experiments were carried out with the herbicides from 1976-1978 on newly-planted and established crops.

METHOD AND MATERIALS

The experiments were carried out at Begbroke Hill on a sandy loam soil having 2-3% organic matter content and pH 6-7. Experiments with trifluralin and propachlor on newly-planted strawberries were carried out in both 1976 and 1977 (Expts 1 and 2). Treatments, planting and herbicide application dates are shown in Table 1. The effects of the herbicides were compared with lenacil at 2 kg/ha (normally a safe treatment on this site).

Pendimethalin and propachlor were applied to newly-planted strawberries in both 1976 and 1977 (Expts 3A and 4A - Table 2). Effects were compared with lenacil and with simazine at 1.5 kg/ha (a damaging treatment in wet seasons). Treatments were repeated on these plots in spring for 1 or 2 years (Expts 3B, 3C, 4A - Table 3).

Strawberry runners, cv. Gorella, were planted 0.25 m apart along rows with 1.5 m between rows. Single row plots 2 m long were used with either 0.5 m discard between plots or 1 m where the experiments had soil-incorporated treatments (Expts 1, 2). Experiments were laid out as randomised blocks with four replicates but with two lenacil treatments per replicate. The following herbicides and formulations were used:- trifluralin, 48% e.c.; pendimethalin, 33% e.c.; propachlor 65% w.p.; lenacil 80% w.p.; simazine 50% w.p.

Herbicides were applied with an Oxford Precision Sprayer at a volume rate of 400 l/ha (530 l/ha for Expts 3C and 4B). Pre-planting treatments were incorporated to a depth of 5 cm within 30 minutes of spraying using a rotary cultivator over the whole experimental area.

Any weeds germinating were killed at the small seedling stage by shallow hand-hoeing. Flower trusses were removed in May in the year of planting. Runners produced in summer were allowed to root to form matted rows. Simazine (1.5 kg/ha a.i.) was applied over the whole experimental area in September each year except in experiment 4B.

Crop vigour was assessed visually at intervals 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). Numbers of rooted runners/plot were counted in the winter after planting. Fruit yield was recorded for crops in their second and third year. In 1977 all the fruit was picked at one time when most of the fruit had ripened. In 1978 successive picks were made over a 2-3 week period.

RESULTS

Pre-planting applications of trifluralin and propachlor alone or in mixture at standard and double rates appeared safe in both years (Table 1). There was a temporary check to growth (leaf stunting) with the double rate of the mixture but no effect on growth when recorded a year after treatment. Treatment with propachlor (4.5 kg/ha) post-planting following pre-planting trifluralin was also safe.

In 1976 pendimethalin and propachlor caused little visible damage to newly-planted strawberries when applied alone or in mixture at the standard rates. At the double rate pendimethalin + propachlor caused more check to growth but this was outgrown by the summer and there was no adverse effect on the number of rooted runners recorded a year after treatment (Table 2).

Table 1

The response of newly-planted strawberries to trifluralin and propachlor applied alone or in mixture or sequentially

Herbicide	Dose (kg/ha)	Timing in relation to planting*	Expt 1 (planted 20/3/76) Vigour score (0-9) 11/5/76	Expt 1 Vigour score (0-9) 4/6/76	Expt 1 Rooted runners (No/m²) 3/3/77	Expt 2 (planted 4/4/77) Vigour score (0-9) 20/5/77	Expt 2 Vigour score (0-9) 20/6/77	Expt 2 Rooted runners (No/m²) 29/3/78
Lenacil	2.0	PS	6.8	7.9	102	7.8	7.4	52
Propachlor	4.5	I	6.8	8.0	115	9.0	7.8	49
	9.0	I	6.5	7.5	93	8.0	6.5	58
Trifluralin	1.1	I	6.8	7.5	103	8.5	8.3	58
	2.2	I	6.3	7.5	96	8.0	7.0	53
Trifluralin	1.1+4.5	I	6.8	8.0	106	8.5	8.3	51
+ propachlor	2.2+9.0	I	6.0	6.8	109	7.5	6.0	54
Trifluralin + propachlor	1.1 4.5	I PS	6.8	7.8	107	8.5	8.5	52
Propachlor	4.5	PS	7.0	8.3	110	8.3	8.0	60
SE ±			0.23	0.33	5.8	0.32	0.44	3.4
LSD 5%			0.6	0.8	NS	0.8	1.1	NS
1%			0.8	1.1	NS	1.0	1.5	NS
0.1%			1.0	1.5	NS	1.4	2.0	NS

*I, herbicide applied and incorporated 19/3/76 and 30/3/77; PS, herbicide applied after planting, 1/4/76 and 6/4/77

Table 2

The response of strawberries to post-planting applications of pendimethalin and propachlor alone or as mixtures

Herbicide*	Dose (kg/ha)	Expt 3A, 1976 (planted 19/3/76)			Expt 4A, 1977 (planted 2/4/77)			
		Vigour score (0-9)		Rooted runners (No/m^2)	Vigour score (0-9)			Rooted runners (No/m^2)
		11/5/76	4/6/76	3/3/77	20/5/77	20/6/77	15/8/77	29/3/78
Lenacil	2.0	7.6	8.8	95	8.3	8.0	8.6	56
Simazine	1.5	7.5	7.5	98	3.5	2.8	3.3	18
Pendimethalin	1.5	8.0	9.0	106	7.0	8.0	9.0	63
	3.0	7.8	8.0	98	6.0	6.5	8.8	63
Propachlor	4.5	7.5	8.5	99	8.5	9.0	9.0	59
	9.0	7.0	8.3	99	7.3	8.3	9.0	62
Pendimethalin + propachlor	1.5+4.5	7.0	8.0	96	6.5	7.3	9.0	57
	1.5+9.0	7.0	8.0	91	6.8	7.8	9.0	60
	3.0+4.5	7.5	8.0	102	6.5	7.0	9.0	62
	3.0+9.0	6.8	7.3	98	5.8	6.0	9.0	59
SE $\pm$		0.29	0.29	5.8	0.31	0.39	0.44	4.6
LSD 5%		0.7	0.7	NS	0.8	1.0	1.1	12
1%		NS	1.0	NS	1.0	1.3	1.5	15
0.1%		NS	1.3	NS	1.3	1.7	1.9	20

*Herbicides applied 1/4/76 and 15/4/77

Table 3

The response of 1 and 2 year-old strawberries to applications of pendimethalin and propachlor alone or as mixtures

Herbicide	Dose (kg/ha)	1 year old strawberries: Expt 3B, 1977 treatments*			1 year old strawberries: Expt 4B, 1978 treatments+			2 year old strawberries: Expt 3C, 1978 treatmentsø		
		Vigour score (0-9) 21/4	Vigour score (0-9) 23/6	Fruit yield (t/ha)	Vigour score (0-9) 25/5	Vigour score (0-9) 23/6	Fruit yield (t/ha)	Vigour score (0-9) 22/5	Vigour score (0-9) 23/6	Fruit yield (t/ha)
Lenacil	2.0	8.0	9.0	10.3	8.8	9.0	33.5	8.9	9.0	34.6
Simazine	1.5	7.0	6.0	6.8	3.3	4.0	12.9	5.3	6.5	21.5
Pendimethalin	1.5	6.3	9.0	12.3	7.5	9.0	36.1	6.0	9.0	34.2
	3.0	5.8	7.0	12.2	5.8	7.5	34.5	5.0	8.5	35.8
Propachlor	4.5	7.0	9.0	12.8	9.0	9.0	36.7	9.0	9.0	35.3
	9.0	5.8	9.0	13.3	9.0	9.0	36.9	8.8	9.0	36.1
Pendimethalin + propachlor	1.5+4.5	5.8	9.0	13.4	8.3	9.0	35.2	7.8	9.0	34.9
	3.0+9.0	5.0	7.0	12.7	6.5	7.5	34.9	6.3	9.0	36.1
SE ±		0.25	0.07	0.61	0.42	0.35	2.22	0.20	0.16	1.42
LSD 5%		0.6	0.16	1.5	1.1	0.9	5.5	0.5	0.4	3.5
1%		0.8	0.2	2.0	1.4	1.2	7.3	0.7	0.5	4.7
0.1%		1.1	0.3	2.7	1.8	1.5	9.6	0.9	0.7	6.2

*sprayed 24/3/77 +sprayed 16/4/78 øsprayed 12/4/78

In 1977 pendimethalin alone, or in mixture with propachlor, caused more leaf stunting than in 1976 but there were no long term effects on runner growth (Table 2); propachlor at the double rate also checked growth temporarily. Simazine had no adverse effect in 1976 compared with lenacil but caused severe damage (leaf chlorosis and necrosis and plant death) in 1977.

When applied to 1 and 2 year-old strawberries pendimethalin caused leaf-stunting and distortion particularly at the double rate (Table 3). The distortion took the form of downward bending and stunting of leaflets and shortening of petioles on leaves growing out in the 1-2 months after treatment. Symptoms were generally out-grown by mid-June and there were no noticeable effects on flower or fruit appearance. Pendimethalin + propachlor mixtures caused the same or a lower level of leaf damage compared with pendimethalin alone. Propachlor alone caused noticeable check to growth of the 1 year-old crop in 1977 particularly at the double rate but not in 1978 (Table 3). Simazine caused a moderate degree of leaf chlorosis and necrosis in both years (Expts 3B, 3C).

In 1977 total fruit yield from all rates of pendimethalin and propachlor and the mixture was significantly higher than from the lenacil treatment but there was no difference in 1978 (Table 3). However, in 1978, when yields were very large, a significantly greater amount of fruit was picked on the first two dates from many of the treatments with pendimethalin or pendimethalin + propachlor compared with lenacil (Fig. 1). Simazine reduced yield severely in both years (Table 3).

DISCUSSION

Propachlor appears to be a safe herbicide for use in strawberries. Not only wer newly-planted crops undamaged by rates up to 9 kg/ha incorporated before planting or sprayed immediately after planting but the same doses re-applied to the plots in the second and third year were also safe. Weather conditions in spring varied from very dry in 1976 (when simazine caused no damage, Table 2) to wet in 1977 and 1978 (when simazine was damaging, Tables 2, 3). Tests elsewhere in the U.K. have also indicated its safety (Loughgall, 1977; Lawson and Wiseman, 1978). Propachlor should therefore be useful in strawberries, either alone, where the weed species are susceptible or in mixture with other residual herbicides. Applied with herbicides such as lenacil or chlorthal dimethyl it would extend the number of weed species controlled and, possibly, allow reduced doses of these herbicides to be used.

A further use of propachlor is following pre-planting trifluralin, a sequence widely used in vegetable crops. Incorporation of a mixture of trifluralin and propachlor pre-planting was safe but results of work elsewhere suggests that the effectiveness of propachlor is often reduced by incorporation (Walker and Roberts, 1975). Post-planting treatment with propachlor following trifluralin had no adverse effect on growth in either year (Table 1) and this would appear to be a safe and effective treatment.

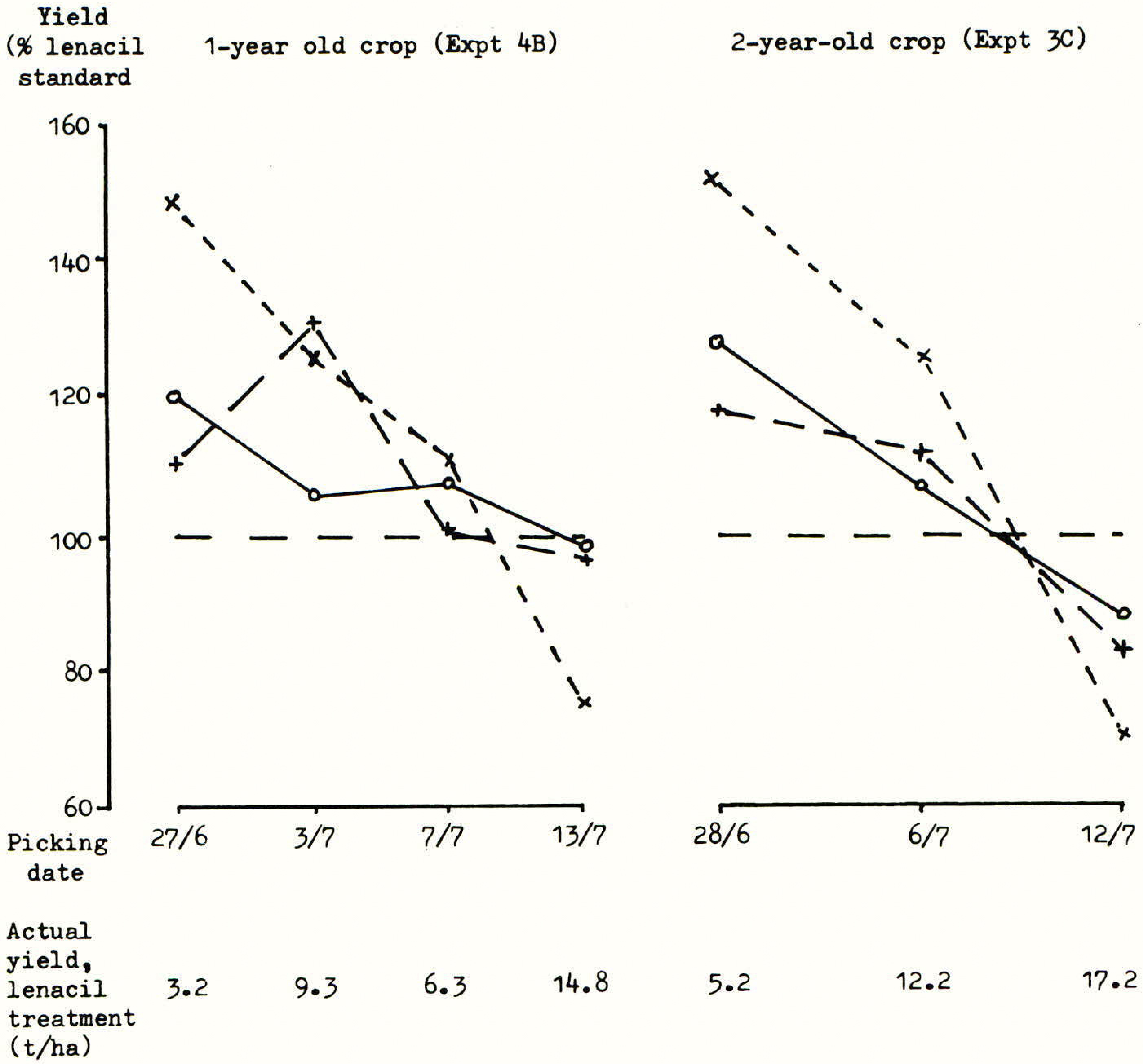
Pendimethalin at 1.5 kg/ha appears safe in newly-planted strawberries in these trials (Table 2) and those elsewhere (Clay et al., 1974, Loughgall, 1977; Lawson and Wiseman, 1978). It has given appreciably better control of annual weeds than lenacil in dry conditions (Clay et al., 1974). The mixture with propachlor broadens the range of weed species controlled; this mixture was safe to the crop at the standard rates (Table 2). Further work is needed with this mixture to establish its effectiveness on a wider range of soils and weed populations than tested so far.

Established crops appear to tolerate pendimethalin alone or with propachlor although some check to leaf growth was found in both years from the standard and double rates (Table 3). This check in fact had a beneficial effect in terms of fruit production in that there was a 20-30% higher yield compared with lenacil in 1977

Fig. 1

The effect of pendimethalin ± propachlor on the weight of fruit harvested at different dates

pendimethalin 1.5 kg/ha (+); 3.0 kg/ha (x); 1.5 kg/ha + propachlor 4.5 kg/ha (o)



(Table 3) and a larger amount of fruit ripening early in 1978 (Fig. 1). These effects seem likely to be the result of the leaf check (by increasing water/nutrient supplies to the flowering trusses or by reducing leaf shading) rather than an adverse effect of lenacil. This is supported by the results with the double rate of propachlor which checked leaf growth in 1977 and gave a 20% yield increase over the lenacil treatment whereas in 1978 when no leaf check was observed yields were similar to lenacil and there was no effect on fruit ripening. In view of these effects it is possible that pendimethalin in spring could have adverse effects on crops which are less vigorous than those in these experiments. Varietal differences in response may also be important. But with vigorous crops the results suggest that some control of leaf growth of vegetative growth in spring may be worthwhile. In raspberries reduction of the competition from new canes by spraying off the first flush with dinoseb-in-oil has lead to significant yield increases (SHRI, 1977). A similar improvement might be possible by reducing the amount of leaf in vigorously-growing strawberry crops.

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THE TOLERANCE OF STRAWBERRY TO 2,4-D, MCPA, MECOPROP AND DICHLORPROP APPLIED IN THE YEAR OF PLANTING

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Summary 2,4-D amine at 2.5 kg/ha was applied at four dates in the year of planting to spring-planted runners of ten strawberry cultivars. A comparison of 2,4-D amine, MCPA, mecoprop and dichlorprop was made on the cultivar Gorella. The effect on the number of crowns and fruit yield is described.

May and June were the safest months to apply the herbicides. Yield reductions from the July application were mainly from the daughter crowns; malformed fruit was produced by the September application.

The most commonly grown cultivars in Britain were among the most tolerant to 2,4-D amine while Pantagruella and Senga Gigana were particularly susceptible.

MCPA, mecoprop and dichlorprop killed some plants of the cv. Gorella and severely reduced yields.

It is concluded that 2,4-D amine is a relatively safe treatment in newly-planted strawberries and is preferable to other growth-regulator herbicides. Timing of application is important and its use in certain cultivars should be avoided.

INTRODUCTION

The only U.K. label recommendation for the control of perennial broad-leaved weeds in strawberries is for glyphosate applied to free-standing weeds through the Croptex Herbicide Glove. Several of the perennial weeds that occur in strawberries, including *Cirsium arvense* and *Convolvulus arvensis*, are controlled by growth-regulator herbicides (Fryer and Makepeace, 1972). Davison and Bailey (1976) reported that 2,4-D amine was relatively safe in the year of planting to four strawberry cultivars particularly when applied early in the year. More information is needed on the tolerance of strawberry to the growth-regulator herbicides in the year of planting, as this is a time when the presence of fruit is not a limiting factor and the timing of the application can be determined by the weed stage of growth.

The two experiments described investigated the tolerance of ten strawberry cultivars to 2,4-D amine applied at four dates in the year of planting (expt. A) and compared the tolerance of the cv. Gorella to 2,4-D amine, MCPA, mecoprop and dichlorprop (expt. B).

METHOD AND MATERIALS

The strawberries in both experiments were planted on 23 March 1976 in a sandy loam soil at Begbroke. The planting distances were 2 x 1.5 m and each plot consisted of the parent plant and all its runners. Flower trusses were removed in the year of planting and the runners were trained in a 90° arc from the parent plant. The ten cultivars are listed in Table 1.

Table 1

The stage of growth of each cultivar at each application date

	Date of application									
	27 May*	22 June			23 July			17 Sept		
Cultivar	a	a	b	c	a	b	c	b	c	d
Cambridge Favourite	1.0	6.5	1.3	2.5	15.0	2.5	9.3	3.0	11.3	23.3
C. Vigour	1.0	7.3	2.3	3.3	14.8	3.0	9.0	3.3	11.5	14.3
C. Prizewinner	1.0	6.3	1.3	1.5	10.3	1.3	6.3	2.3	9.5	9.8
C. Premier	1.0	6.8	1.8	2.3	13.0	2.3	8.3	1.8	9.0	15.5
Redgauntlet	1.0	6.3	2.0	2.5	10.0	1.8	6.8	2.5	13.0	21.5
Gorella	1.0	8.0	2.0	3.3	14.0	2.8	9.8	2.3	11.3	18.8
Domanil	1.0	7.3	2.0	1.8	16.3	3.0	10.3	4.5	10.8	16.0
Royal Sovereign	1.0	4.3	1.8	2.0	13.5	3.0	7.5	2.0	9.0	11.0
Pantagruella	1.0	8.3	2.5	2.8	13.5	2.5	11.0	2.8	17.5	26.5
Senga Gigana	1.0	6.3	2.0	3.0	13.5	2.0	8.3	2.8	11.2	20.3

a Number of leaves on the parent plant
b Number of crowns on the parent plant
c Number of runners
d Number of daughter plantlets

*Does not include the leaves present at the time of planting

Annual weeds were controlled with herbicides. Lenacil at 2 kg/ha a.i. was applied in April followed by phenmedipham at 1.5 kg/ha a.i. to control emerged seedling weeds. Weed control was maintained throughout the following year by an application of simazine at 1.0 kg/ha a.i. in the winter. Insecticides and fungicides were applied as necessary to control foliar pests and diseases. A soil drench of 200 ml of 0.2% benomyl was given to each plant on the day of planting to check verticillium wilt (*Verticillium dahliae*).

The experimental treatments, 2,4-D (32% amine), MCPA (65% potassium salt), mecoprop (50% potassium salt) and dichlorprop (50% potassium salt), at 2.5 kg/ha a.i., were applied with an Oxford Precision Sprayer fitted with Lurmark LP 20 fan nozzles. The pressure was 0.5 bar and the volume rate 400 l/ha. The dates of application (which were the same for both experiments) and the stages of crop growth are given in Table 1. The treatments were replicated four times and the experimental design was a randomised block.

Notes were made of the foliar symptoms in the year of treatment but the main assessments were crown counts and fruit yield in the following year. Because the runners had been trained away from the parent plant, separate assessments were made on the parent and its daughter plants.

Where differences are stated as being significant, $p = 0.05$.

RESULTS

Experiment A. The tolerance of ten cultivars to 2,4-D amine

All treatments caused epinasty of petioles and runners, and the first two or three leaves expanding after application showed formative effects. Pantagruella and Senga Gigana had the most severe symptoms whereas those on Cambridge Premier were hardly noticeable. The only deaths were of cvs. Pantagruella (two plants from 16 treated) and Senga Gigana (four plants). These occurred at the July and September application dates. Leaves expanding after the two or three with formative effects were always normal and there were no foliar symptoms in the year after treatment. The fruit in the year after treatment was normal except on those plants treated in September where a small proportion were crescent-shaped and occasionally fused together.

The number of crowns on the parent plants in May, the year after treatment, are presented in Table 2. These were only reduced significantly by five treatments; the June and September applications to Senga Gigana, the June and July applications to Pantagruella and the September application to Domanil.

Table 2

The number of crowns on the parent plant in the year after treatment

Cultivar	Untreated	Date of application 27 May	22 June	23 July	17 Sept	
Cambridge Favourite	6.0	5.3	4.3	5.5	4.3	
C. Vigour	6.3	5.6	6.5	6.5	6.3	
C. Prizewinner	3.8	3.0	3.3	4.3	3.3	
C. Premier	3.8	5.5	4.5	4.3	4.0	
Redgauntlet	3.9	4.5	3.3	4.0	3.3	
Gorella	4.8	5.5	4.8	4.5	3.8	
Domanil	5.0	6.3	8.5	4.3	_2.8_	
Royal Sovereign	5.0	3.5	3.8	4.5	5.3	
Pantagruella	5.3	4.3	_3.3_	_2.5_	3.8	
Senga Gigana	5.8	6.0	_2.3_	4.3	_3.0_	SE $\pm$ 0.68

Figures underlined are significantly different from the untreated control

There was more effect on the number of crowns on the daughter plants than on the parent plant (Table 3). The May application significantly reduced the numbers on Gorella, Royal Sovereign and Pantagruella and the June application signifiantly reduced numbers on all cultivars except Cambridge Vigour, C. Prizewinner and Gorella. The July application reduced the numbers on all cultivars by more than 36% and the numbers on Royal Sovereign, Pantagruella and Senga Gigana were all reduced by more than 75%. There were reductions with the September application but they were only significant on Cambridge Favourite, Redgauntlet, Gorella, Royal Sovereign, Pantagruella and Senga Gigana. The latter was particularly susceptible at this date with a reduction of 89%.

Table 3

The number of crowns on daughter plants in the year after treatment

Cultivar	Untreated	Date of application 27 May	22 June	23 July	17 Sept
Cambridge Favourite	41	43 (104)	26 (62)	21 (52)	18 (42)
C. Vigour	32	29 (91)	25 (76)	15 (47)	27 (85)
C. Prizewinner	24	28 (117)	24 (100)	8 (33)	19 (79)
C. Premier	36	38 (105)	25 (69)	23 (63)	30 (83)
Redgauntlet	49	41 (84)	37 (76)	17 (35)	30 (61)
Gorella	41	30 (73)	33 (79)	17 (42)	23 (56)
Domanil	29	22 (75)	7 (24)	9 (31)	20 (70)
Royal Sovereign	44	32 (71)	15 (33)	9 (20)	25 (55)
Pantagruella	51	27 (52)	9 (18)	11 (21)	31 (61)
Senga Gigana	35	34 (97)	1 (3)	6 (17)	4 (11)

SE $\pm$ 3.84

Figures in parentheses are the % of the untreated for each cultivar
Figures underlined are significantly different from the untreated control

Fruit yields from the parent plant are given in Table 4. There were some reductions from the May, June and July applications, but only those from the July application to Pantagruella (54%), and the June and July applications to Senga Gigana (67% and 75% respectively) were significant. The September application reduced the yield of all cultivars by over 20% but reductions were only significant on Cambridge Favourite (68%), Domanil (80%) and Senga Gigana (88%).

Table 4

Fruit yield from the parent plant (g/plant)

Cultivar	Untreated	Dates of application 27 May	22 June	23 July	17 Sept
Cambridge Favourite	621	598 (96)	435 (70)	559 (90)	197 (32)
C. Vigour	606	471 (78)	985 (163)	644 (106)	466 (77)
C. Prizewinner	302	258 (85)	184 (61)	225 (75)	127 (42)
C. Premier	333	527 (158)	521 (156)	482 (145)	180 (54)
Redgauntlet	596	372 (62)	418 (70)	417 (70)	306 (51)
Gorella	326	247 (76)	525 (162)	362 (111)	171 (53)
Domanil	679	1049 (154)	963 (142)	689 (101)	137 (20)
Royal Sovereign	327	242 (74)	260 (80)	202 (62)	141 (43)
Pantagruella	592	525 (89)	360 (61)	271 (46)	310 (52)
Senga Gigana	609	615 (101)	203 (33)	150 (25)	73 (12)

SE $\pm$ 98.4

Figures in parentheses are the % of the untreated for each cultivar
Figures underlined are significantly different from the untreated control

The combined yield from the parent and daughter plants is given in Table 5. The only cultivar in which the May application significantly reduced the yield was Pantagruella (49%). The June application caused significant reductions of over 44% with Domanil, Royal Sovereign, Pantagruella and Senga Gigana; the reduction with the other cultivars was never greater than 21%. Yields of all cultivars were reduced with the July and September applications. The reductions from the July application ranged from 16% for Cambridge Premier to 85% for Senga Gigana and with the September date from 24% for C. Premier to 96% for Senga Gigana. The only reductions that were not significant at these dates were those for Redgauntlet and C. Premier at both dates, from Gorella and C. Prizewinner in July and C. Vigour in September.

Table 5

Total fruit yield from both parent and daughter plants (kg/plant)

Cultivar	Untreated	27 May	22 June	23 July	17 Sept
Cambridge Favourite	2.85	2.86 (100)	2.24 (79)	1.70 (60)	0.63 (22)
C. Vigour	3.00	2.19 (73)	2.86 (95)	1.88 (63)	2.13 (71)
C. Prizewinner	1.75	2.21 (126)	1.49 (85)	0.88 (50)	0.63 (36)
C. Premier	1.67	2.58 (155)	1.82 (109)	1.40 (84)	1.26 (76)
Redgauntlet	2.49	2.00 (80)	2.85 (114)	1.73 (70)	1.49 (60)
Gorella	2.33	2.34 (101)	2.57 (111)	1.43 (61)	1.14 (49)
Domanil	2.84	2.84 (100)	1.60 (56)	1.44 (51)	0.55 (19)
Royal Sovereign	2.56	1.85 (72)	0.96 (38)	0.68 (27)	0.66 (26)
Pantagruella	4.33	2.21 (51)	1.11 (26)	1.18 (27)	1.37 (32)
Senga Gigana	3.37	3.77 (112)	0.28 (8)	0.52 (15)	0.13 (4)

SE $\pm$ 0.38

Figures in parentheses are the % of the untreated for each cultivar
Figures underlined are significantly different from the untreated control

Experiment B. 2,4-D amine, MCPA, mecoprop and dichlorprop on Gorella

From a total of 16 plants treated with each herbicide 2,4-D amine killed none but MCPA killed six, mecoprop five and dichlorprop nine.

The combined yield from the parent and its daughter plants is given in Table 6. 2,4-D amine did not reduce the yield at either the May or June application dates but the reductions from the July and September application dates were 42 and 44% respectively.

Yields were significantly lower with MCPA, mecoprop and dichlorprop than with 2,4-D amine. The differences in yield between MCPA, mecoprop and dichlorprop were never significant but the trend was for MCPA to be less damaging than the other two; MCPA reduced the yield by 44% in May compared with 67 and 68% with mecoprop and dichlorprop. The corresponding reductions for June and July were 61, 81 and 97% and 89, 94 and 99%. The September application gave reductions of over 95% with all three herbicides.

Table 6

The effects of 2,4-D amine, MCPA, mecoprop and dichlorprop on the yield of cv. Gorella in the year after planting

Herbicide	Date of application: 27 May	22 June	23 July	17 Sept
2,4-D amine	2485 (121)	2570 (125)	1201 (58)	1143 (56)
MCPA	1159 (56)	811 (39)	236 (11)	74 (4)
mecoprop	678 (33)	401 (19)	115 (6)	43 (2)
dichlorprop	664 (32)	68 (3)	11 (1)	1 (0)
untreated	2059	SE ± 315		

Figures in parentheses are the % of the untreated

DISCUSSION

The management of the crop in these experiments may have exaggerated the results. All runners were retained and by training them away from the parent plant the competition between the parent and daughter plants was minimised. Commercially the planting density is greater, fewer runners are retained and the daughter plants would not account for such a large proportion of the yield as they did in these experiments. Therefore some of the differences that were significant in the experiments may not be commercially important.

Luckwill and Lloyd-Jones (1960) reported that 2,4-D is rapidly degraded by strawberry. This would explain why epinasty was only seen on the leaves and runners present at the time of application and why formative effects were confined to the two or three leaves expanding afterwards.

Least damage was from the May and June applications when very few runners had been produced. The majority of runners had been produced by July and damage to these runners caused most of the yield reductions at this date. The malformed fruit from the September application was due to the application coinciding with the onset of fruit bud initiation. For crops grown as spaced plants rather than matted rows the period when 2,4-D amine is relatively safe can be extended into July because at that date the yield from the parent plant of most cultivars was unaffected.

The most widely-grown cultivars in Britain, including Cambridge Favourite, were among the most tolerant to 2,4-D amine, but two of the more recent introductions, Pantagruella and Senga Gigana, were particularly susceptible. Where land is known to be infested with perennial broad-leaved weeds the planting of these two cultivars should be avoided.

Davison (1972) reported that 2,4-D amine was the safest of several growth-regulator herbicides applied to strawberries planted the previous autumn. This work also shows that in newly-planted strawberries 2,4-D amine is safe. It did not kill any of the commonly-grown cultivars whereas MCPA, mecoprop and dichlorprop killed more than 30% of the treated plants of Gorella. Therefore 2,4-D amine should be used in preference to the other herbicides.

There were no perennial weeds in these experiments and in interpreting these results, the consequences of not controlling these weeds has to be considered. As well as competing with the crop, weeds such as Cirsium arvense and Convolvulus arvensis will result in the fruit being unpicked. In addition, if left unchecked, the weedy areas will spread.

There is normally enough weed growth before the end of June for 2,4-D amine to give a useful kill of the weed roots. This treatment, although not eliminating the weed, should check the spread of weedy patches, delay emergence of shoots in the following year and reduce their numbers thus extending the life of the crop. 2,4-D amine can damage strawberries and applications should be confined to weedy areas.

These experiments were designed to investigate the tolerance of spring-planted runners to 2,4-D amine. It cannot be assumed that cold-stored summer-planted runners or autumn-planted runners would behave similarly in their tolerance to 2,4-D amine in the year of planting. Ester formulations of 2,4-D should not be used on strawberries until the crop tolerance has been established.

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NOTES

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FURTHER STUDIES ON THE USE OF GLYPHOSATE ON FRUIT TREES WITH ROOT SUCKERS

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Summary Root suckers of apple, cherry, pear and plum trees were sprayed with glyphosate at 7.5 kg/ha a.e. In one year sprays were applied to the bases of mature suckers as would occur in a normal weed control practice, whilst in the following season current year suckers were sprayed overall. Sprays were applied in May, June or July to trees with mature suckers and in July to trees with young suckers.

In both sets of experiments glyphosate caused no damage to the parent tree in either the year of treatment or the subsequent year. Sprayed suckers were killed or damaged. Depending on the fruit species, sucker control varied from 35-96% for applications to mature suckers and from 67-100% for young suckers. In all cases sucker re-growth in the succeeding year was much less than in un-sprayed trees.

INTRODUCTION

Standard herbicide programmes in most top fruit orchards usually depend upon a restricted range of residual compounds and can lead to a build up of perennial weed species. Many of these perennials can be controlled with glyphosate e.g. Bailey and Davidson (1974), Seddon (1974). These perennial weed problems tend to be more extensive around mature fruit trees that often possess root suckers which would be sprayed during the application of glyphosate to perennial weeds. Atkinson (1977) and Atkinson, O'Kennedy, Abernethy and Allen (1978) simulated the application of standard rates of glyphosate to the bases of apple, cherry, pear and plum suckers during weed control operations. They found that application during winter and in May, June and July caused no damage to the trees and gave some control of the suckers.

However, during spraying, as a result of inadequate machine calibration, or of the operator's inattention, or mistakes, suckers may receive application at rates much higher than those recommended. This paper presents data on the effect of high rates of glyphosate on tree and sucker performance. In the studies conducted by Atkinson (1977) and Atkinson et al. (1978) glyphosate was applied only to the base of old (2 and 3 year) suckers and so the effect of applying high rates of glyphosate to the whole of current year suckers has now been studied.

METHOD AND MATERIALS

Experiments were carried out in 1976 and 1977 using trees of apple (26-year trees of Lane's Prince Albert on M.7), cherry (10-year trees of Merton Crane on F12/1), pear (10-year trees of Conference on Quince A) and plum (17-year trees of Victoria on St. Julien A). All trees were grown in either herbicide squares or herbicide strips with grassed alleys.

1976 Experiment

All trees had many 1 and 2-year suckers at the beginning of the 1976 trial. The average number of suckers was apple 29, cherry 112, pear 62 and plum 47.

Trees were sprayed with glyphosate at 7.5 kg/ha a.e. in 500 l. of water so as to simulate a normal herbicide application for weed control. Sprays were directed so as to wet only the lower 10-15 cm (approximately) of the suckers. The area to be treated was selected so as to encompass the suckers present and varied between the kinds of fruit. Tree trunks were also wetted during spraying. Trees were sprayed on 4th May, when buds had recently burst and on 9th June and 9th July when both suckers and trees were in full leaf. On all dates buds or leaves were usually present within the portion of the suckers sprayed.

Plots were arranged so as to contain approximately similar numbers of suckers. Treatments were applied to 6 replicates of single trees. Records were also made on control (unsprayed) trees.

Trees and suckers were examined at intervals during 1976 and in late spring 1977. Damage to trees was recorded on a 1-5 scale (undamaged-dead). Sucker growth was assessed in autumn 1976 and the number and length of dead, damaged and healthy suckers recorded. Suckers were classed as dead if they had damaged bark and prematurely dead leaves. The regrowth of suckers was assessed in spring 1977 as the number of growing shoots.

1977 Experiment

Except for the following modifications, the 1977 experiment was carried out as in 1976. All pre-existing suckers were removed in April, at approximately 5 cm height from both the treated and control trees used in the 1976 experiment. They were then allowed to regrow and at the beginning of the trial the average number of current year suckers present was apple 35, cherry 61, pear 11 and plum 9.

Trees sprayed in 1976 were sprayed again in 1977 with the same rate of glyphosate except that the whole of the sucker length and not merely the base was sprayed during the period 20th-26th July. Trees and suckers were examined for damage in November 1977 and again in May 1978.

RESULTS

Effects on the parent tree

No damage was found to the trees of any of the fruit kinds during either the year of treatment or the subsequent spring in both experiments.

Effects on the suckers

The best control of suckers resulted from the July spray for the pome fruits, apple and pear, and the June spray for the stone fruits, plum and cherry (Table 1). For pome fruits damage was similar on a length and number basis, but for stone fruits was higher on a number basis.

Table 1

The % number and length of dead suckers at the end of the year of treatment for the 1976 experiment

Species	Date of spraying					
	May		June		July	
	No.	Length	No.	Length	No.	Length
Apple	2a	2a	9a	11a	96b	95b
Cherry	15a	9a	35b	27b	19a	12a
Pear	14a	17a	37a	40a	51b	50a
Plum	7a	3a	60b	57b	30b	16b

Comparable values followed by a different letter are significantly different at P >0.05

In all species regrowth was least in the treatments showing the greatest effect in the previous year. In these trees regrowth was generally higher in stone fruit than in pome fruit (Table 2).

Table 2

The number of suckers growing in 1977 as a % of the number of suckers in 1976

Species	Date of spraying			Control
	May	June	July	
Apple	211ab	295b	14c	162
Cherry	146a	89b	123a	
Pear	206a	65b	43b	
Plum	186a	118b	316a	

Comparable values followed by a different letter are significantly different at P >0.05

In both pome fruits there was almost a total kill although in the stone fruits sucker death was less complete (Table 3). In plum, but not cherry, the kill was greatest in the trees previously sprayed in June 1976 and this treatment showed the greatest effect in that year.

Table 3

The % number of dead suckers at the end of the year of treatment for the 1977 experiment

Species	Date of 1976 spraying		
	May	June	July
Apple	100b	100b	95a
Cherry	51a	55a	67a
Pear	100a	100a	100a
Plum	74a	100b	82c

Comparable values followed by a different letter are significantly different at P >0.05

In all fruit kinds regrowth seemed unaffected by the date of the 1976 spray and was very much less than that of the control trees (Table 4). Regrowth was again less in pome than in stone fruit. Although many new cherry and plum suckers grew they were half as numerous as the controls. In all species most of the new suckers on sprayed trees were much less vigorous than those on unsprayed trees and many showed glyphosate damage symptoms as described by Putnam (1976).

Table 4

The number of suckers growing in 1978 as a % of suckers in 1977

Species	Date of 1976 spraying			Control
	May	June	July	
Apple	22b	24b	33b	104a
Cherry	127b	123b	123b	243a
Pear	38b	8b	10b	283a
Plum	113b	136b	114b	204a

Comparable values followed by a different letter are significantly different at P >0.05

DISCUSSION

If glyphosate is sprayed on to 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 in the following year (Davison, 1975). However, Putnam (1976), Atkinson (1977) and Atkinson *et al.* (1978), showed that when conventional rates of glyphosate (up to 2.5 kg/ha a.e.) were applied to root suckers on a range of dates the trees were apparently undamaged either in the year of treatment or the following year. In the current study a similar result was obtained with much higher doses of chemical regardless of whether the chemical was applied to established 2 and 3-year suckers or to current year suckers.

Together, these studies suggest that during winter, spring and summer there is no translocation of absorbed glyphosate from root suckers to the parent tree. Observations on the regrowth of damaged suckers indicated that regardless of whether suckers were treated at the base only or overall, the severity of damage was always greatest at the sucker tip and the strongest regrowth occurred at the base. This suggests that glyphosate is preferentially moved acropetally within shoots for most of the year and this protects the tree from damage after spraying suckers.

Sucker competition with the parent tree for resources, can be a major problem in intensive systems and may act as reservoirs of disease. Thus the ability of a herbicide to kill suckers without damaging the parent tree would be of great value. Depending on the fruit species the application of glyphosate to suckers during the course of a simulated weed control spray killed from 35-96% of mature suckers present. Sprays directed specifically at young suckers gave complete control in all species except cherry where there was up to 67% control. Sucker control using glyphosate appears to be at least as good as that with a single application of some other chemicals. Quinlan (1974) obtained from 70% (pear) to 94% (apple) control with a NAA shoot tipping agent. He obtained 100% control with cherry, but using trees which had many fewer suckers than those in this study.

These studies, which utilized a range of fruit tree material, indicated that spraying glyphosate on to root suckers at very high rates during the period May-July caused no damage to parent trees and with young suckers gave almost complete control for some species.

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PRELIMINARY RESULTS ON THE USE OF FOSAMINE IN FRUIT TREES

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Summary Fosamine was sprayed on root suckers of mature apple and pear trees during July. There was no detectable damage to the parent apple trees although most suckers were damaged during the year of treatment and the number emerging in the subsequent year was reduced. Pear suckers were affected more than apple and some of the parent trees were damaged. Spraying individual branches of pear trees resulted in the death of the sprayed branch and death or damage to other branches. Because of this evidence that Fosamine is translocated in pear trees it should not be sprayed on pear suckers.

INTRODUCTION

The need for weed control in fruit orchards is generally accepted and standard residual herbicide programmes are widely used. However, the continuous use of this type of material can result in the build up of perennial weed species. Increasingly these now include woody species such as hawthorns (*Crataegus monogyna*) and oak (*Quercus* species). A material which would kill woody weeds without damaing fruit species would be a valuable addition to available herbicides. Fosamine will kill deciduous trees and shrubs in coniferous plantations and non-cropland situations (Anon, 1976; Schwerdtfeger and Allison, 1976). However, Fosamine is reported to be toxic to *Malus* and *Prunus* species (Anon, 1976) and so the susceptibility of fruit species under orchard conditions required evaluation.

Older fruit trees, around which perennial weed problems are most common, often have many root suckers that would be sprayed during most weed control operations. Although Schwerdtfeger and Allison (1976) have suggested that Fosamine usually lacks systemic activity the possibility remained that suckers would translocate it to the parent tree.

METHOD AND MATERIALS

Trees of apple (27-year Lane's Prince Albert/M.7) and pear (11-year Conference/Quince A) grown in herbicide strips with grassed alleys were used. All trees had 1-2-year suckers at the beginning of the trial, the average being 66 and 74 for apple and pear respectively.

Experiment 1: Sprays applied to the suckers

Trees were sprayed with Fosamine at 0.24 kg a.i./ha as a 2% solution of the commercial formulation to which the wetter "Agral" was added. Sprays were applied to simulate a normal herbicide application and most suckers, which were 40 cm high at spraying, were wetted. The treated area around the tree was selected to encompass the suckers present. Sprays were applied on 20th July, when both suckers and the parent trees were in full leaf. There were 8 replicates of single tree plots. Trees and suckers were examined at intervals during 1977 and in spring 1978. Damage to trees was expressed on a 1-5 scale (undamaged-dead) and the numbers and length of dead, damaged and healthy suckers were recorded.

Experiment 2: Direct effects on the tree

Individual marked branches (under 1 m in length) of 6 pear trees were sprayed with Fosamine at the previous concentration on 20th July. Measurements were made as for the sucker experiment.

RESULTS

Effects on the parent trees

The application of Fosamine to suckers had no effect on the parent trees of either species during the year of treatment or in apple in the subsequent year. Fosamine damaged 4 of the 8 treated pear trees (Table 1). Damage caused by Fosamine was similar to that by glyphosate, i.e. narrowing and reduction in size of the leaf lamina, in rolling of the leaf margins, etc.

Table 1

The effect of spraying pear root suckers or individual scion branches on tree performance in the year after spraying

	Effect on suckers	Effect on sprayed branch	Effect on remainder of tree
	Damage index		
Scion branch sprayed	1.5 range 1-4	5	2.0 range 1-4
Root suckers sprayed	5	-	1.6 range 1-3

During the year of treatment, the application of Fosamine to individual branches of pear trees killed the treated branch, but caused no damage to the rest of the tree. In the subsequent year damage (mild to severe) was found on 3 of the 6 sprayed trees (Table 1). Branches both above and especially below the treated branch were damaged.

Effects on the suckers

Although few pear suckers were killed most were damaged (Table 2). During the year of treatment in both species the suckers began to die back from the tip and showed bark discolouration. Regrowth in the following year, relative to unsprayed trees, was reduced in both species although the effect was greatest in pear (Table 3).

Table 2

The % of suckers dead, damaged and healthy at the end of the year of treatment

Species	% dead	% damaged	% healthy
Apple	21	65	14
Pear	16	84	0

Table 3

The number of suckers growing in 1978 as a % of those growing in 1977

Species	Treatment	
	Fosamine sprayed	Unsprayed control
Apple	85	99
Pear	2	283

In one of the 6 pear trees where a branch of the scion was sprayed there was some sucker death (Table 1).

DISCUSSION

It has been suggested that deciduous trees produce few leaf symptoms in the year of application of Fosamine, major effects showing in the following year (Anon, 1976). In this study application to the foliage of pear trees killed the treated shoots in the year of application. Some damage to both apple and pear suckers in the year of treatment was also obvious. Apple and pear seem more sensitive to Fosamine than many of the species discussed by Schwerdtfeger and Allison (1976). In the year after application there was a marked suppression of the regrowth of pear suckers.

Schwerdtfeger and Allison (1976) showed that Fosamine has little systemic activity in most woody species, although the activity which they found against *Convolvulus arvensis* and *Pteridium aquilinum* indicated that there was some basipetal translocation in these.

The effect of Fosamine on pears in this study shows that it can move basipetally out of suckers and both basipetally and acropetally in the parent tree. The damage pattern on sprayed scion branches and the injury to suckers suggests that basipetal transport predominates.

Suckers compete with the parent tree for water and for carbon resources; they are a considerable problem in intensive orchard systems and can act as a reservoir of diseases such as plum pox. A chemical able to kill suckers and move basipetally from a treated stump might be of great value in treating plum pox infected trees where it is important to kill all living material.

Although the ability to kill root suckers is a valuable attribute for any herbicide the trials described here suggest that, in pear at least, Fosamine should not be applied where it could contact growing root suckers and that it must be used with great care in pear orchards.

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