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THE RESPONSE OF STRAWBERRY TO A RANGE OF FOLIAGE ACTING HERBICIDES

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Summary The tolerance of strawberries to foliar applications of thirteen herbicides was tested in glasshouse experiments. 4-nitro-2,4, 6- trichlorodiphenyl ether (MO 338), pentanochlor, phenmedipham and pyrazone caused little injury at rates recommended for weed control. In a further glasshouse experiment pyrazone 3 kg/ha as a foliar spray caused no injury to four strawberry cultivars (Cambridge Favourite, C.Vigour, Redgauntlet and Senga Sengana). Little or no injury was caused to the same cultivars growing in sand treated with pyrazone at concentrations up to 1 ppmw dry sand. In an observation trial, summer application of pyrazone at 3 and 6 kg/ha to strawberries in the field caused no visible effect on growth or runner production. MO 338 at 3 and 6 kg/ha caused slight scorch on exposed leaves but plants quickly grew out of this. Pentanochlor at 3 and 6 kg/ha caused more leaf scorch and growth inhibition but plant growth after 1 month appeared normal.

These three herbicides would appear to be worth further trial for the control of emerged weeds in strawberries.

INTRODUCTION

The need for foliage-actingherbicides to control annual weeds in strawberries has become more acute in recent years. Severe weed problems have arisen either from the failure to use the recommended soil-acting herbicides at the right time or from the growth of weeds which have some resistance to these herbicides. Particular problems have come from annual grass weeds and from broad-leaved weeds such as Veronica spp., Polygonum aviculare, Galium aparine and Viola arvensis.

Phenmedipham has been used successfully to control certain seedling weeds in strawberries, in particular Veronica spp. (Robinson and Rath, 1970) but the use of this herbicide can result in scorch to the crop when used in certain climatic conditions and other problem weeds are not controlled.

In an attempt to find alternative foliage-acting herbicides for use in strawberries a number were tested on the crop in spring and summer 1972. The herbicides were generally selected on the grounds that they were already recommended for the control of particular problem weeds (Fryer and Makepeace, 1970) and that they were, or would be, commercially available.

The foliar activity of thirteen herbicides was tested on strawberries in glasshouse experiments (Experiments 1 and 2). The effect of foliage and root treatments with pyrazone was also tested on four cultivars in a pot experiment (Experiment 3). Three herbicides, MO 338, pentanochlor and pyrazone were later tested in an observation trial in the field.

METHODS AND MATERIALS

Experiment 1   The strawberry plants used were runners of cv. Cambridge Favourite which had been potted-up in vermiculite in 12.5 cm diam. pots in late November and grown on in the glasshouse under supplementary illumination. The plants were watered with dilute nutrient solution (¼ strength Hewitt's solution) from above as necessary. At the time of treatment the plants had from eight to twelve expanded leaves. Just before herbicide treatment a layer of perlite was put over the pot surface to prevent any spray reaching the rooting medium. The perlite was removed shortly after spraying. Plants were sprayed on 28/3/72 using a laboratory pot sprayer. This was fitted with a T-jet (8002) and gave a volume rate of 352 l./ha at a pressure of 2.1 kg/cm^2. One herbicide, phenmedipham, was, however, sprayed at a volume rate of 225 l./ha using a smaller T-jet (8001) at the same pressure. The 2 kg/ha rate of phenmedipham was applied by spraying the plants twice. There were two replicate plants in each treatment.

Herbicide details and rates

Herbicide	Doses (kg/ha)		Formulation
Aziprotryne	2.0	4.0	50% w.p.
Benazolin	0.5	2.0	30% a.c.K salt
Bentazon	2.0	4.0	50% w.p.
Bromoxynil	0.25	1.0	25% e.c. octanoate ester
Glyphosate	0.5	2.0	36% a.c. isopropylamine salt
Methabenzthiazuron	2.5	5.0	70% w.p.
Metoxuron	4.0	8.0	80% w.p.
MO 338	2.0	6.0	20% e.c.
Phenmedipham	1.0	2.0	11.4% e.c.
Pyrazone	2.5	5.0	80% w.p.
RP 17623 *	1.0	4.0	25% e.c.

After spraying the plants were moved back to the glasshouse and stood in aluminium foil dishes. Subsequent watering was from below either with tap water or dilute nutrient solution.

Visual assessments of injury were made at intervals on the following 0 to 7 scale.

0 = plant dead;
1 = moribund but not all tissue dead;
2 = alive with some green tissue but unlikely to make further growth;
3 = very stunted but still making growth;
4 = considerable inhibition of growth;
5 = readily distinguishable inhibition of growth;
6 = some detectable adverse effect;
7 = indistinguishable from control.

The dry weight of plants was determined 8 weeks after spraying.

Experiment 2   Runners of cv. Cambridge Favourite were planted at the same time as those for experiment 1 but in pots of washed sand (Leighton Buzzard, Double Arches No.2 pit). Subsequent management and spraying procedure were exactly as in experiment 1. In addition some plants were given a root drench treatment with pyrazone in 50 ml water to determine the susceptibility of strawberries to the herbicide

* 2-tertiarybutyl-4-(2,4-dichloro-5-isopropyloxyphenyl)-(4H)-1,3,4,-oxadiazoline-5-one

in the rooting medium. Herbicide treatment was carried out on 12/5/72 when the plants had 15 to 20 expanded leaves. There were two replicate plants in each treatment.

Herbicide details and rates

Herbicide	Doses (kg/ha)			Formulation
Metoxuron	4.0	8.0		80% w.p.
Metribuzin	1.0	3.0	9.0	70% w.p.
MO 338	2.0	6.0	12.0	20% e.c.
Pentanochlor	2.0	4.0	8.0	40% e.c.
Phenmedipham	1.0	2.0		11.4% e.c.
Pyrazone	2.5	5.0	10.0	80% w.p.

Pyrazone (sand treatment) 0.1, 1.0, 5.0 ppmw dry sand

After treatment the plants were moved back to the glasshouse. Subsequent management of the foliage treated plant was as in experiment 1. The sand treated pots were watered alternately from above and below with tap water or dilute nutrient solution.

Visual assessments of injury were made at intervals and the fresh weight of the plants determined after four weeks.

Experiment 3. Cold stored runners of cultivars Cambridge Favourite, C.Vigour, Redgauntlet and Senga Sengana were planted in pots of sand outside in May 1972. They were transplanted to 12.5 cm diam. pots of sand on 7/6/72 and grown on in the glasshouse with overhead watering with a dilute nutrient solution as necessary. All flower trusses and runners were removed prior to herbicide treatment on 27/6/72 at which time the plants had four or five expanded leaves. Foliar sprays were carried out as for pyrazone in the previous experiments with doses of 2.5, 5.0 and 10.0 kg/ha Sand treatments were carried out by adding the appropriate quantity of pyrazone in 50 ml of water to the sand surface, the pots standing in foil dishes. The rates used were 0.05, 0.2, 0.5, 1.0, 2.5 and 7.5 ppmw dry sand. Subsequent watering was carried out as in the comparable treatments in experiment 2. There were two replicate plants of each cultivar in each treatment.

After treatment the plants were grown on in the glasshouse. Visual assessments of injury were made at intervals and a final count of the number of injured and uninjured leaves was made after four weeks.

Experiment 4. Runners of Cambridge Favourite were planted in a sandy loam soil at Begbroke Hill on 23/3/72 at a spacing of 1.5 m between rows and 0.5 m along rows. The experimental plots measured 1 m^2 and contained two plants. Adjacent plots were separated by one guard plant. The experiment was laid out on a randomised block design with three blocks.

The herbicides were applied on 14/7/72 when the plants each had ten to fifteen expanded leaves and were producing many runners, none of which were rooting. The weather was warm, dry and sunny at the time of spraying (max. air temperature 24°C). A small hand held sprayer fitted with a T-jet (6502) was used at 2.1 kg/cm^2 to apply the appropriate volume of spray to each plot within a square metre hessian screen. MO 338, pyrazone and pentanochlor were each applied at 3 and 6 kg/ha, the first two at a volume rate of 400 l./ha and the pentanochlor at 800 l./ha.

Visual assessment of injury were made at intervals after treatment.

RESULTS

Experiment 1. The symptoms of injury that developed after the herbicide application are described below.

Aziprotryne. Chlorosis of young leaves and interveinal necrosis of older leaves developed 1 to 2 weeks after spraying. Surviving older leaves retained a broad bright yellow margin. Regrowth was normal.
Benazolin. Slight epinasty of sprayed leaves within a week of spraying. New leaves emerging between 1 and 2 months after spraying with 2 kg/ha rate showed severe formative effects.
Bentazon. Marginal and interveinal necrosis of older leaves developed 2 weeks after spraying. Regrowth was normal.
Bromoxynil. Marginal necrosis of exposed leaves developed within a few days of spraying. Many leaves were completely necrotic after 2 weeks. Very young leaves became chlorotic but later regrowth was normal.
Glyphosate. With the lower rate older leaves were unaffected, small expanding leaves became chlorotic and stopped growing and many small chlorotic leaves (<5 cm long) were developed but did not grow out. With the higher rate all expanding leaves died off and there was no regrowth.
Methabenzthiazuron. Interveinal necrosis of exposed leaves developed slowly from 2 weeks after spraying. Regrowth was normal.
Metoxuron. Interveinal necrosis of exposed leaves developed between 2 and 4 weeks after spraying. Regrowth was normal.
MO 338. Necrotic spots developed quickly on the surface of the youngest expanded leaves present when sprayed. Other leaves did not develop symptoms and later growth was normal.
Phenmedipham. The youngest expanded leaves present at spraying developed chlorotic patches within 2 weeks. At the higher rate these leaves also became necrotic. Regrowth was normal.
Pyrazone. Slight marginal chlorosis developed on one or two leaves after 4 weeks.
RP 17623. Symptoms were similar to those from MO 338 but rather more severe, one or two exposed leaves dying. Regrowth was normal.
The degree of injury and final plant weight are shown in Table 1.

The results show that while MO 338, phenmedipham and pyrazone caused phytotoxicity, the effects were slight and had little effect on plant growth (Table 1). Benazolin also caused little effect on the plants but the later development of severely distorted leaves with the higher rate indicates the possible dangers in its use. RP 17623 did not reduce final weight of plants but the degree of scorch caused by the herbicide suggests there is less selectivity than with MO 338. Metoxuron caused little injury at first suggesting the plant might possess some resistance to the herbicide but after 2 months significantly reduced plant growth. The other herbicides caused an unacceptable degree of injury and were not considered for subsequent experiments.

Experiment 2. For MO 338 and phenmedipham the symptoms of herbicide injury in this experiment were similar to experiment 1. The degree of injury and effect on final fresh weight is shown in Table 2. With pentanochlor (8kg/ha), marginal necrosis of the oldest leaves developed within 2 weeks of spraying. Later these symptoms developed on plants treated with 4 kg/ha and chlorotic patches developed on the sprayed leaf surfaces at all rates of the herbicide. Regrowth was normal. Metribuzin caused necrosis after 1 week, expanding leaves becoming chlorotic. Regrowth from the 1 kg/ha rate was normal. Foliage treatment with pyrazone caused slight marginal chlorosis of oldest leaves at the end of the growing period. These symptoms were also caused by root treatment with 1 ppmw. The 5 ppmw rate caused severe necrosis of older leaves. There were no significant reductions in plant weight after 6 weeks with any treatments except metribuzin at all rates, metoxuron at 8 kg/ha and root treatment with pyrazone at 5 ppmw.

Table 1

The effect of eleven herbicides on growth and final weight of strawberries

Treatment (dose kg/ha)		Vigour score (scale 0 - 7) 1 month after spraying	2 months after spraying	Dry wt.of plants (g) 2 months after spraying
Aziprotryne	2.0	3.5	4.5	6.3*
	4.0	3.5	4.5	5.6*
Benazolin	0.5	6.0	6.5	12.5
	2.0	6.0	4.5	11.5
Bentazon	2.0	4.5	5.0	6.8*
	4.0	4.5	5.5	7.3*
Bromoxynil	0.25	4.0	5.0	7.6*
	1.0	3.0	4.0	4.1*
Glyphosate	0.5	4.5	3.5	9.3*
	2.0	4.0	0.5	0.7*
Methabenz-thiazuron	2.5	4.5	5.0	6.3*
	5.0	4.0	5.0	5.7*
Metoxuron	4.0	5.5	5.5	6.4*
	8.0	5.0	4.5	5.0*
MO 338	2.0	7.0	6.5	11.5
	6.0	6.0	6.0	9.4*
Phenmedipham	1.0	6.0	6.5	13.1
	2.0	5.0	4.5	9.1*
Pyrazone	2.5	7.0	6.5	12.6
	5.0	7.0	6.0	12.1
RP 17623	1.0	5.5	5.5	10.9
	4.0	5.0	5.5	10.2
Control		7.0	7.0	12.3
		S.E. of means		± 0.81
		l.s.d. (p=0.05)		2.4

* significant reduction in weight compared with control.

Table 2

The effect of six herbicides on growth and final fresh weight of strawberries

Treatment Foliage spray (kg/ha)		Vigour score (0-7) after 3 weeks	Vigour score (0-7) after 6 weeks	Fresh wt. of plants (g) 6 weeks after spraying
Metoxuron	4.0	6.0	4.0	136*
	8.0	5.0	3.0	96
Metribuzin	1.0	4.0	4.5	115*
	3.0	3.0	0.0	0*
	9.0	3.5	1.0	42*
MO 338	2.0	6.5	7.0	166
	6.0	5.5	6.0	192
	12.0	6.0	5.0	167
Pentanochlor	2.0	6.0	6.0	169
	4.0	6.0	6.0	144
	8.0	5.0	5.0	144
Pyrazone	2.5	6.5	6.5	162
	5.0	6.0	6.5	188
	10.0	6.5	6.0	158
Sand treatment (ppmw)				
Pyrazone	0.1	6.5	7.0	184
	1.0	7.0	6.0	173
	5.0	5.5	4.5	113 *
Control		7.0	7.0	193
		S.E. of means		± 30.4
		l.s.d. (p=0.05)		63

* significant reduction in fresh weight compared with control

Experiment 3. Table 3 shows that foliage treatments with pyrazone this time caused slight marginal and interveinal chlorosis at all rates and on all cultivars, with slight necrosis developing at the 10 kg/ha rate. Root treatment with 1 ppmw pyrazone caused only slight effects but the higher rates caused considerable interveinal necrosis on leaves of all cultivars. There was no big difference in response between cultivars.

Experiment 4. Application of MO 338 to the field plots caused rapid blackening of the surface of exposed leaves both on established plants and well developed runners but the crop quickly grew out of this check (Table 4). Pentanochlor at 3 kg/ha caused chlorotic patches and slight necrosis of exposed leaves; the 6 kg/ha rate caused more severe necrosis on exposed leaves and chlorosis on developed runners but regrowth after six weeks was normal. The pyrazone treatment appeared to have no adverse effect on the crop.

Table 3

The effect of foliar and root applications of pyrazone on growth of four cultivars of strawberries

Treatment Foliar Spray (kg/ha)	Vigour score (0-7) 1 month after treatment F*	V	R	S	% leaves showing herbicide injury 1 month after treatment F	V	R	S
2.5	6.0	6.0	6.0	6.5	0	0	7	0
5.0	6.0	6.0	5.5	6.0	0	0	12	0
10.0	5.5	5.5	5.0	5.0	0	0	51	45
Sand treatment (ppmw sand)								
0.05	7.0	7.0	7.0	7.0	0	0	0	0
0.20	7.0	7.0	7.0	7.0	0	0	0	0
0.50	7.0	7.0	7.0	7.0	0	0	0	0
1.00	6.0	7.0	6.5	6.0	0	0	18	16
2.50	4.5	5.5	5.0	5.0	24	22	39	20
7.50	3.0	4.0	3.5	3.0	83	50	64	91
Control	7.0	7.0	7.0	7.0	0	0	0	0

* Key to cultivars - F = Cambridge Favourite R = Redgauntlet
S = Senga Sengana V = Cambridge Vigour

Table 4

The effect of application of MO 338, pentanochlor and pyrazone on strawberries in the field

Herbicide	dose (kg/ha)	Vigour score (0-7) 1 week after spraying	2 weeks after spraying	6 weeks after spraying
MO 336	3	5.0	6.0	7.0
	6	4.0	5.3	6.3
Pentanochlor	3	5.0	5.3	6.0
	6	4.0	4.0	5.3
Pyrazone	3	7.0	7.0	7.0
	6	7.0	7.0	7.0
Control		7.0	7.0	7.0

DISCUSSION

In the glasshouse experiments, MO 338, pentanochlor, phenmedipham and pyrazone were all tolerated by strawverries at rates required for weed control. Benazolin, metoxuron and RP 17623 did not cause much growth inhibition at herbicidally effective doses but the short term scorch or long term effects on growth were thought to be unacceptable, so later experiments did not include them. The other herbicides tested at rates required for weed control all resulted in considerable leaf injury or growth reduction. In the third experiment foliar applications of pyrazone were shown to be tolerated by four of the strawverry cultivars most widely grown in Britain. The experiment also confirmed that there was a fair measure of tolerance to root exposure to the herbicide.

The observation trial in the field confirmed that the herbicides tested could be of value for post-emergence weed control. Phenmedipham was not tested in this trial becaused of the difficulty of achieving accurate application of low volumes of herbicide to small plots. MO 338 and pentanochlor again gave some scorching of leaves but the crop appeared to recover quickly.

A certain degree of leaf yellowing or scorch is also associated with the use of phenmedipham in the field (Robinson and Rath, 1970).

To decide on the acceptability of using herbicides that cause such injury, the economic loss from any check to the crop must be compared with that which would result from unchecked weed growth or with the cost of hand weeding. Further work will be necessary with these herbicides to determine their usefulness for controlling problem weeds and the effects of their use on growth and yield, particularly in relation to climatic conditions and stage of growth of the crop. MO 338 was developed in Japan (Noda and Ozawa, 1971) and there are no reports of field trials in Britain. Extensive crop tolerance trials are in progress with phenmedipham at a number of centres. Pentanochlor has been used in Britain (Hancock, 1972) but further work on strawberries is needed particularly in view of reports of extensive injury elsewhere (Rushdy, 1968). Pyrazone would be worthy of investigation for use in strawberries in view of the wide range of seedling weeds it can control.

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THE RESPONSE OF STRAWBERRY TO APPLICATIONS OF 2,4-D, MCPA, MCPB, MECOPROP AND DICHLORPROP DURING THE GROWING SEASON

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Summary 2,4-D, MCPA, MCPB, dichlorprop and mecoprop were applied at 2.5 kg/ha between July and October to strawberry cv. Cambridge Favourite planted the previous autumn. All treatments had an adverse effect on crop growth initially. By the following summer, ground-cover scores showed considerable recovery from some treatments. The safest chemical was 2,4-D. The others caused severe damage except when applied at the end of July. Plant counts and truss weights in the season after treatment supported the ground cover assessments, indicating the potential usefulness of 2,4-D for the control of perennial broad-leaved weeds in strawberries.

INTRODUCTION

The reduction in mechanical weed control associated with increased use of soil-acting herbicides for the control of annual weeds in strawberries is resulting in an increase in problems with perennial broad-leaved weeds which are not controlled by the treatments that are recommended in the United Kingdom (Fryer and Makepeace, 1970). Growth-regulator herbicides which would be effective in controlling such weeds have in the past been applied experimentally to strawberries for the control of annual weeds. Early work in England showed that MCPA, MCPB and 2,4-D when applied to the cv. Cambridge Prizewinner in August caused damage at herbicidally effective doses (Rosewarne, 1956). Maiden plants of Royal Sovereign sprayed after the onset of runner production in late July were also damaged, but it was noticed that 2,4-D was less damaging than MCPB (Roach, 1957). In North America 2,4-D amine at 1.1 kg/ha caused no damage when applied 6 weeks after planting the cv. Premier, but in 2 out of 3 seasons two applications (6 and 10 weeks after planting) reduced yield and four applications always reduced yield by about 50% (Hill, 1958). Elsewhere in North America considerable variation in susceptibility was found among the 18 cultivars tested (Hemphill, 1959). At Loughgall, in Northern Ireland, where much of the work was with Cambridge Vigour and the object was to control *Ranunculus repens* many of the treatments were applied in the winter. Mecoprop at doses as low as 0.56 kg/ha reduced yields when applied in February, March and April. With the cv. Talisman there was no significant effect on plant size or crop yield when three formulations of 2,4-D (sodium salt, triethanolamine and butoxyethylester) were applied at 2.2kg/ha in November and January. When 2,4-D was applied to Cambridge Vigour at seven different times for three successive seasons (1.1kg/ha the first year and 2.2kg/ha thereafter) there was an average yield reduction of 15-25% with applications when growth was starting (March), pre-blossom (April-May) and at flower-bud differentiation (September). But at post-harvest (July-August) and when dormant (November and January) there was less than 10% reduction in yield. There were also indications that MCPA was more damaging than 2,4-D and both were more damaging than the corresponding butyrics (Loughgall, 1960, 61 and 62).

The present work was undertaken with the object of determining the response of strawberry to several growth regulator herbicides applied at different times of the year. 2,4-D, MCPA, MCPB, dichlorprop and mecoprop were all applied at 2.5kg/ha, a dose which should give adequate control of many weeds.

Table 1

Application details and stage of crop

Application date	Herbicides					Crop
	2,4-D*	MCPA*	MCPB*	dich* lor prop	meco* prop	Stage of runner development
1 July	x	x	x	.	.	3 leaves - no roots
29 July	x	x	x	x	x	starting to root
3 Sept.	x	x	x	x	.	well rooted
14 Oct.	x	.	.	.	.	well established

x = treatment applied
. = no treatment

* 2,4-D	32% w/v	diethanolamine
MCPA	25% w/v	potasium salt
MCPB	40% w/v	sodium salt
dichlorprop	50% w/v	potasium salt
mecoprop	58% w/v	sodium salt

METHOD AND MATERIALS

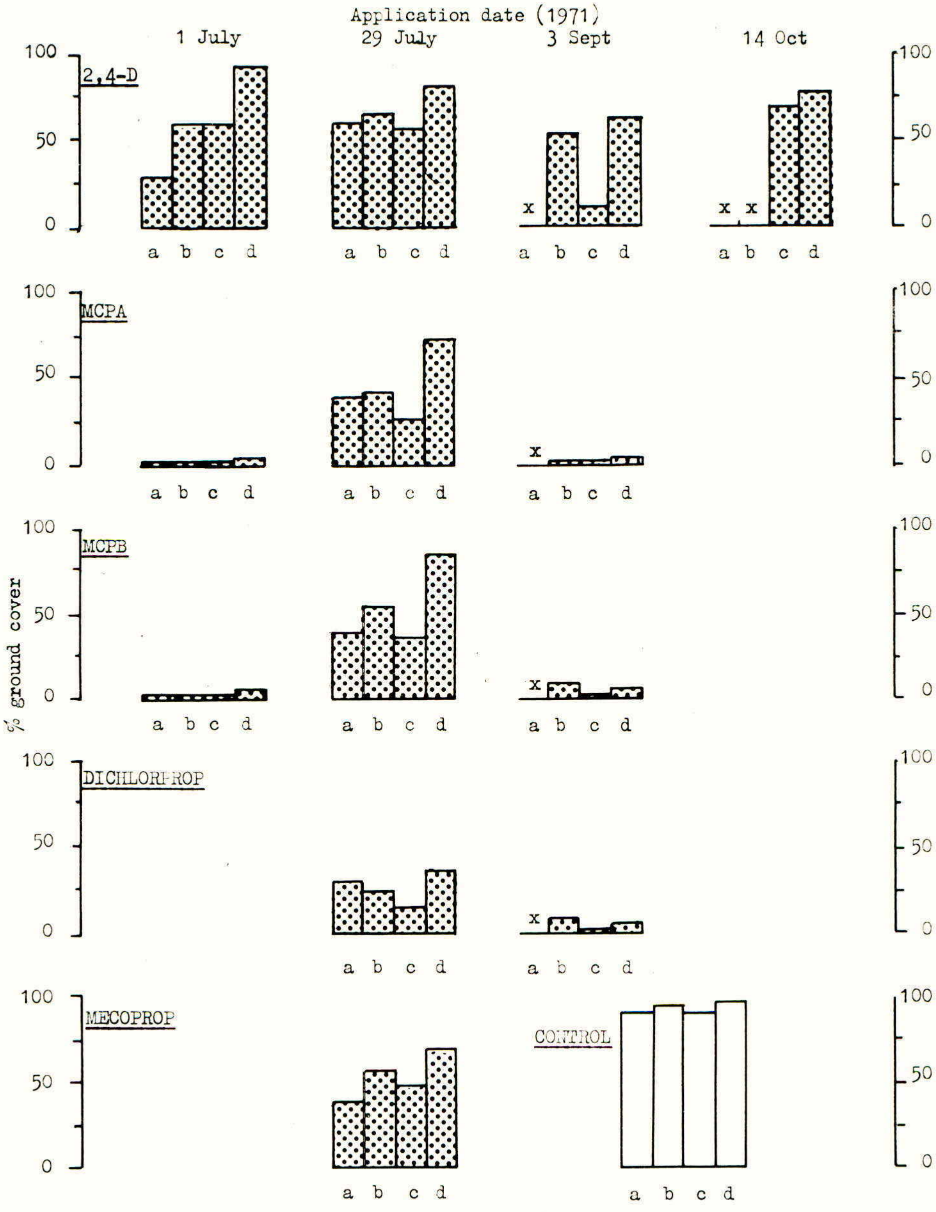
Two experiments were carried out in a commercial plantation of strawberry cv. Cambridge Favourite that was planted in autumn 1970 and trained into matted rows in 1971. The crop received routine applications of residual herbicides and pesticides. Table 1 indicates the stage of crop growth - and the dates on which the herbicides were applied. Plots were 0.9 x 3.6m. Each plot was only sprayed once. Treatments were arranged in randomised blocks and replicated three times. The first two treatment dates formed one experiment and the third and fourth another on adjacent rows.

All treatments were applied at 2.5 kg/ha, in either 720 l/ha (Expt. 1) or 540 l/ha (Expt. 2) with an Allman no. 6 fan nozzle at 0.7 kg/cm^2. Crop growth was vigorous throughout the experiment. At the outset parent plants had a spread of 40 cm increasing to 50 cm and a height of 25 cm.

Visual assessments were made at intervals. On 29/7 and again on 26/8/71 the parent plants and runners were scored separately on a 0-10 linear scale. However on the second date it was difficult to distinguish the two ages of plant and an overall crop cover score was also made. At subsequent assessments on 3/9 and 14/10/71 and on 16/3, 13/4 and 15/6/72 no attempt was made to distinguish original plants from 1971 runners. The number of actively growing crowns on 2 x 0.9m lengths of row on each plot was counted on 13/4/72. On 29/6/72 when flowering was almost finished and the largest fruits were 3.5 cm diameter and just starting to ripen, the fruit trusses from 1m of row were removed and weighed.

Figure 1. Strawberry - % ground cover on 4 dates

a = 26/8/71, b = 14/10/71, c = 16/3/72, d = 15/6/72



x = no treatment

RESULTS

<u>Plant Vigour</u> Figure 1 presents histograms of the percentage of the ground covered by strawberry foliage when assessed on 26/8 and 14/10/71 and on 16/3 and 15/6/72 for the untreated controls - and the five herbicides applied at different dates.

MCPA and MCPB at the first application date caused considerable damage. After one month there was no new growth. The sprayed leaves were twisted and had reddened petioles. Both parent plants and runners were affected. With 2,4-D the effect on both parent plants and runners was less severe although they could still be readily distinguished from the untreated plants. After a further month the MCPA and MCPB had killed the new runners and there was still no regrowth on the parent plants. With 2,4-D the parent plants had only been checked and there were new runners although in terms of ground cover there was only about a third as much as on the controls. Figure 1 shows that the second treatments, applied on 29 July, were much less damaging and of the five herbicides applied, there was least injury with 2,4-D. Assessments made on 14 October show that the third application in early September also resulted in severe damage with MCPA, MCPB and also with dichlorprop, but as with the first application, there was relatively little damage with 2,4-D.

In the following year there was little change, there being no recovery from the first or third applications that had caused severe damage in the year of treatment. Figure 1 shows that in March 1972 there was a slight reduction in ground cover with all the treatments applied on 29 July 1971, but the 2,4-D treatment in early September 1971 that had 50% ground cover in October 1971 was reduced to less than 20% in March and April 1972. However, by mid-June there was considerable recovery. Careful inspection up to the end of June 1972 failed to reveal any abnormality in leaves, flowers or fruit on any plots that could be attributed to the treatments applied the previous year.

<u>Number of living crowns</u> The number of living crowns was counted in April 1972. The data presented in Table 2 is the Log (x + 1) transformation of the number of crowns in 2 x 1m lengths of row, with detransformed means in parenthesis. In Experiment 1 application of MCPA and MCPB on 1 July resulted in significantly fewer crowns as did all the treatments that were applied on 29 July. At the latter date there were significantly fewer crowns with dichlorprop than with the other four herbicides. MCPA, MCPB and 2,4-D were applied on both dates; MCPA and MCPB at the first date resulted in significantly fewer crowns than when they were applied at the second date. In Experiment 2 there were significantly fewer crowns with MCPA and MCPB applied in early September than with 2,4-D applied at the same time or in mid-October. The reduction caused by 2,4-D was not significant.

Immediately before the crowns were counted percentage ground cover was assessed and it was found that there was a positive correlation that was very highly significant ($r = 0.9618$).

<u>Weight of fruit trusses</u> The results in Table 3 are the Log (x + 1) transformations of the fresh weight in g of complete fruit trusses from 1m of row, with the detransformed data in parenthesis. In Experiment 1 applications of MCPA and MCPB on 1 July were the only treatments that resulted in significant reductions. In Experiment 2 MCPA and MCPB applied in early September also significantly reduced truss weight whereas 2,4-D at the same date and in mid-October did not.

DISCUSSION

The results presented confirm those of earlier worker in showing that the strawberry is more tolerant to 2,4-D than to the other growth-regulator herbicides tested. It is particularly interesting to note that more damage was caused by MCPB than by

Table 2

The number of living crowns in 2m of crop row on 13/4/72

Data has undergone Log (x + 1) transformation (detransformed means in parenthesis)

Treatment	Expt. 1 Application date 1/7/71	29/7/71	Expt. 2 Application date 3/9/71	14/10/71
Control	2.20 (158)	2.20 (158)	2.03 (105)	2.03 (105)
2,4-D	2.03 (106)	1.99 (97)	1.79 (60)	1.94 (87)
MCPA	0.75 (6)	1.82 (66)	0.36 (1)	-
MCPB	0.69 (4)	1.93 (85)	1.13 (12)	-
Dichlorprop	-	1.63 (41)	0.68 (4)	-
Mecoprop	-	1.88 (75)	-	-
S.E.of Log (x + 1) treatment means	0.063	0.063	0.114	0.114

- = no treatment

Table 3

Truss weight in g for 1 m of row on 29/6/72

Data has undergone Log (x + 1) transformation (detransformed means in parenthesis)

Treatment	Expt. 1 Application date 1/7/71	29/7/71	Expt. 2 Application date 3/9/71	14/10/71
Control	2.81 (638)	2.81 (638)	2.71 (512)	2.71 (512)
2,4-D	2.80 (630)	2.64 (437)	2.62 (416)	2.71 (512)
MCPA	1.66 (45)	2.79 (611)	0.94 (8)	-
MCPB	1.14 (13)	2.76 (573)	1.24 (16)	-
Dichlorprop	-	2.62 (420)	1.24 (16)	-
Mecoprop	-	2.79 (616)	-	-
S.E.of Log (x + 1) treatment means	0.209	0.209	0.356	0.356

- = no treatment

2,4-D and that there was very little difference between MCPA and MCPB. The apparent greater tolerance to herbicides other than 2,4-D at the second date can only be attributed to the stage of growth. This corresponds with the post-harvest period which was also found to be one of the safest periods in Northern Ireland (Loughgall, 1962).

Truss weight at the onset of ripening only provides a very approximate guide to fruiting potential, since it indicates neither the number of fruits nor their relative stage of maturity. Nevertheless, when it approaches the untreated control it can be assumed that there will be a whorthwhile yield. The number of living crowns is more meaningful, especially when regrowth is normal as it was in these experiments, since it will have a direct effect on subsequent cropping. Within certain limits reduction in the number of crowns may be acceptable or even desirable, since excessive numbers of plants can lead to a reduction in fruit size or yield, especially under conditions of moisture stress.

In considering these results it is essential to consider the context in which there may be a need to apply a growth-regulator herbicide to strawberries. None of the herbicides currently recommended for use in strawberries control established perennial broad-leaved weeds (Fryer and Makepeace, 1970). Yet the increasing cost and declining availability of labour, together with the ineffectiveness of sporadic hoeing as a means of controlling many perennial weeds, calls for effective herbicide treatments. In many cases only small areas of a field need be treated, in which case even complete crop kill may be acceptable and the most effective chemical can be used. Where there are larger patches of weed, or where the entire crop has to be treated, there is more need for a treatment that does not damage the crop. In the absence of a safe and effective treatment the use of 2,4-D appears promising, subject to the acceptance of some risk to the crop. It should also be mentioned that there are many perennial weeds that would be effectively suppressed, especially with MCPA and 2,4-D at doses below 2.5 kg/ha. These low doses may be of value early in the growing season to prevent perennial weeds being a nuisance at harvest. However, except where the weeds are resistant to 2,4-D the use of other herbicides seems inadvisable until there is more information on varietal and seasonal variation since the present work has demonstrated how critical timing is with MCPA, MCPB and dichlorprop.

Acknowledgements

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TOLERANCE OF RASPBERRIES AND STRAWBERRIES TO THE RESIDUES OF PRE-PLANTING COUCHGRASS HERBICIDES

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Summary The tolerance of raspberries and strawberries to the residues of aminotriazole, dalapon, trichloroacetic acid (TCA) and EPTC are reported including data on the time taken for each herbicide to reach 100% loss of toxicity as shown by lettuce and oat bioassay. The evidence shows that raspberries can be planted 2 weeks after aminotriazole applications and 6 weeks after spraying with dalapon or a mixture of dalapon plus aminotriazole. TCA remained toxic to raspberries for 8 weeks and EPTC caused cane death 10 weeks after application.

Strawberries showed satisfactory growth 6 weeks after aminotriazole, aminotriazole plus dalapon and TCA treatments, but 8 weeks delay was necessary before planting in dalapon alone or EPTC treated soil.

INTRODUCTION

Recently significant advances have been made towards the control of perennial grass weeds, especially *Agropyron repens*, in established crops of raspberries and strawberries with herbicides such as terbacil (Rath & Robinson 1970), bromacil (Lawson & Rubens 1970) or pronamide (Sumpter 1970). Although established raspberries show good tolerance to overhead applications of any of these herbicides, it has been shown that even well established strawberries are likely to suffer some ill effects from a herbicide such as terbacil (Rath & Robinson 1970). However, competition from *Agropyron repens*, (couch grass) at the immediate post-planting stage presents a very serious problem. Effective weed control at this stage is essential for good crop establishment but unfortunately both raspberries and strawberries show a low tolerance at this stage to herbicides which could be used for couchgrass control. In order that weed competition during this very critical stage be avoided, effective control of perennial grass weeds is required, either pre-planting or during site preparation. However the residues of herbicides applied at this time could damage raspberries and strawberries planted subsequently. Hence this study was designed to investigate the tolerance of raspberries and strawberries to herbicides which are capable of controlling *Agropyron repens*.

MATERIALS AND METHODS

All experiments were conducted on a similar soil type which could be described as a sandy clay loam with the following physical analysis (0 - 2 in.) - 66.4% sand; 11.6% silt; 15.2% clay and 7.3% organic matter as measured by loss on ignition. Herbicides were applied according to manufacturer's recommendations in 50 gallons of water per acre using an Oxford precision sprayer.

In Experiment 1, single rows of raspberries (cv. Malling Jewel) were planted on each plot at 2, 4, 6, 8 and 10 week intervals after the herbicide application.

Plants were spaced 12 in. apart in each row, with a similar distance between successive rows.

Experiment 2 was established in a similar manner using strawberries (cv. Cambridge Vigour) as test plants. Fertiliser dose, pest and disease control followed normal practice. Plants were scored for phytotoxicity using a scale of 0 - 5, where 0 represented a complete kill of all plants on each plot and 5 represented a healthy vigorous growth with no visible symptoms of herbicide injury.

Experiment 3 was designed to assess residual herbicide toxicity. Soil samples were taken at fortnightly intervals at a 0 - 2 in. depth and then air dried before use. Residual herbicide toxicity was measured using the parallel line bioassay technique of Allott and O'Neill (1970). Assays were designed as randomised blocks and each contained an unsprayed soil sample. The percent loss in toxicity is presented for each herbicide, 6 weeks after application. Although Allott and O'Neill (1970) suggested lettuce seedlings (cv. Delta) as the most reliable test species, it was felt that pregerminated oats (cv. Stormont Zephyr) might also prove especially sensitive in this case. Results with both test species are presented. All herbicide doses in this paper refer to active ingredient.

RESULTS

Experiment 1

This experiment was sprayed on 16 March 1971. The first planting of raspberries (cv. Malling Jewel) was on 30 March and continued at fortnightly intervals until 26 May (10 weeks after spraying). Herbicide residual phytotoxicity was scored on 8 September and is presented in Figure 1. From Figure 1 it can be seen that aminotriazole (ATA) had no adverse effects on raspberries from 2 weeks after spraying onwards. Dalapon and dalapon + aminotriazole caused crop injury for 4 weeks but from 6 weeks onwards crop growth was not effected. TCA was toxic for 8 weeks and EPTC for the whole period of the experiment.

Experiment 2

This experiment was established on 8 March 1971, the first planting of strawberries (cv. Cambridge Vigour) was on 24 March. Planting continued at fortnightly intervals until 18 May. Phytotoxicity scores were recorded on 4 June and are presented in Figure 2. Aminotriazole, aminotriazole + dalapon and TCA remained toxic to strawberries for 4 weeks but after 6 weeks satisfactory growth occurred. Dalapon alone and EPTC caused damage for up to 6 weeks and normal plant growth did not occur until a period of 8 weeks had elapsed from the date of spraying.

Experiment 3

This experiment was sprayed on 8 March 1971. Soil samples were taken at 2 week intervals from 22 March and residual herbicide toxicity to both lettuce and oats measured. This was continued until 100% loss of toxicity occurred. The toxicity loss after 6 weeks is presented in Table 1.

It is evident from Table 1 that all herbicides showed a loss of toxicity to lettuce ranging from 62 - 80%. Oats on the other hand appeared slightly less sensitive with toxicity losses ranging from 61 - 99%. In contrast to the lettuce bioassay, the oat bioassay indicated almost complete disappearance of dalapon over the 6 week period and that a substantial residual toxicity due to TCA was still present.

Fig. 1. Decrease with time in residual phytotoxicity to raspberries, following the application of a range of herbicides

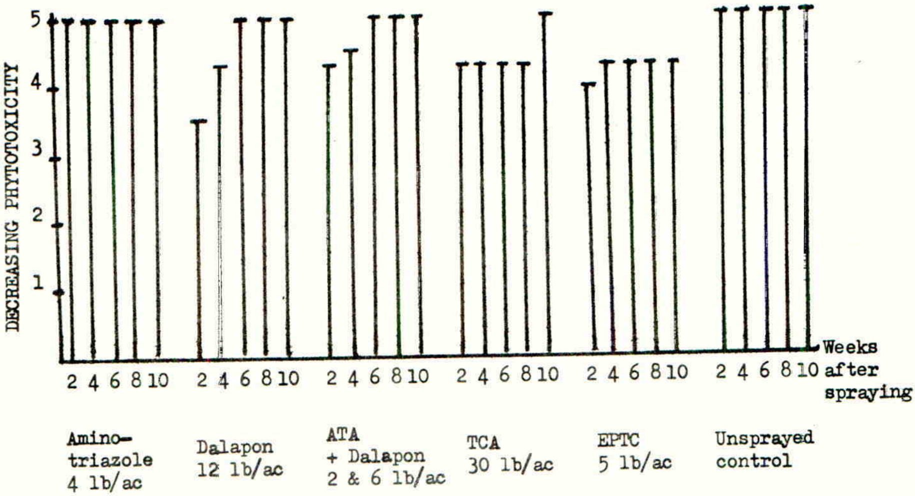

Fig. 2. Decrease with time in residual phytotoxicity to strawberries following the application of a range of herbicides

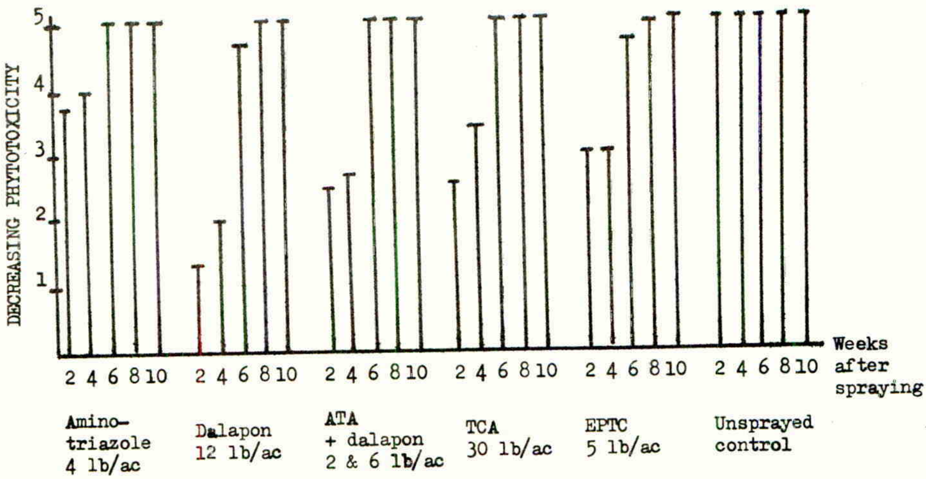

Table 1

% Loss of toxicity of a number of herbicides 6 weeks after application (Expt 3)

Herbicide	Rate	% Loss of toxicity indicated by:- lettuce	oats
Aminotriazole	4 lb/ac	80.0	79.0
Dalapon	12 lb/ac	62.0	99.0
Aminotriazole + dalapon	2 lb/ac + 6 lb/ac	72.0	88.0
TCA	30 lb/ac	80.0	61.0
EPTC	5 lb/ac	72.0	75.0

Table 2

Time taken (weeks) for a number of herbicides to show 100% loss of toxicity (Expt 3)

Herbicide	Rate	Time for 100% loss of toxicity as indicated by:- lettuce	oats
Aminotriazole	4 lb/ac	11	12
Dalapon	12 lb/ac	11	7
Aminotriazole + dalapon	2 lb/ac + 6 lb/ac	12	12
TCA	30 lb/ac	9	12
EPTC	5 lb/ac	9	12

Table 2 presents the time in weeks taken for herbicides to reach 100% loss in toxicity as indicated by the test plants. Lettuce indicated TCA and EPTC to be the least persistent while oats suffered no growth reduction due to dalapon after only 7 weeks. The maximum period of phytotoxicity for any herbicide was 12 weeks, as shown by both test species for the aminotriazole + dalapon mixture.

DISCUSSION

Though Experiment 3 shows that a period of up to 12 weeks can be required for the phytotoxic effects of couchgrass herbicides to completely disappear Experiments 1 and 2 indicate that raspberries and strawberries are sufficiently tolerant to permit planting appreciably sooner than this. The tolerance of raspberries even to small residues of either TCA or EPTC is very questionable, but good tolerance to aminotriazole, dalapon or mixtures of these is apparent after 6 weeks (Fig. 1). Strawberries on the other hand showed an initial susceptibility to all herbicides for up to 4 weeks but they are apparently tolerant thereafter; dalapon and EPTC treated land should not be planted for about 8 weeks however, as slight leaf symptoms were visible after 6 weeks.

In the 2 weeks following herbicide application a total of only 0.22 in. of rain fell and soil temperature at 1 in. depth ranged from 3.4 - 8.2°C. Caseley (1970) found that the activity of aminotriazole and dalapon was not influenced by soil temperature but Håkansson (1970) reported better activity of TCA at low soil temperatures (7 - 10°C). The soil temperature range recorded during these experiments would appear to have been favourable for the action of most herbicides. However, soil moisture probably is a more important influence than temperature in this particular case. The low rainfall shortly after spraying undoubtedly reduced herbicide activity and possibly prolonged soil persistence. Experiments 1 and 2 were repeated in 1972 (results not presented) when the rainfall for 2 weeks after spraying was 0.82 in. Establishment of both raspberries and strawberries was good on all treatments even 2 weeks after spraying, except on EPTC treated plots. These still remained toxic after 10 weeks. The earlier establishment of crops during 1972 is thought to be due to higher soil moisture conditions resulting in a more rapid disappearance of herbicides. EPTC did not seem to be influenced by the soil moisture difference which occurred in the 2 years. On this basis therefore 1971 provided a very critical test for both raspberries and strawberries.

Anpalov (1970) carried out a similar series of experiments in Russia and found that 12 weeks were necessary before planting strawberries in TCA or dalapon treated soil. Higher rates of application and different soil and climatic conditions undoubtedly influenced his results, which suggests that the results presented in this paper cannot be considered in isolation and used for commercial recommendations without more extensive research under different soil and climatic conditions. They do however confirm the possibility of using herbicides to control couchgrass close to planting and when, due to lack of sufficient advance warning of the presence of rhizomes in a prospective field the chance of using more elaborate control measures has been missed.

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TOLERANCE OF ESTABLISHED RASPBERRY PLANTATIONS TO A RANGE OF RESIDUAL HERBICIDE TREATMENTS

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Summary Fluometuron, bromacil, terbacil and atrazine applied before cane emergence had no adverse effect on fruiting cane yield or any aspect of new cane production in the year of treatment or in the following year. Maximum rates applied (lb a.i./ac) were fluometuron 6.6, bromacil and terbacil 6.0 and atrazine 8.0. Chlorthiamid and dichlobenil at 8.3, 16.5 and 24.8 lb a.i./ac reduced the numbers of canes produced between the stools and delayed cane growth in the stool at the beginning of the season, but had no effect on the proportions of stool cane removed during the winter or retained for fruiting. No effects on yield of fruiting cane or on subsequent cane growth were found. Treatment with chlorthiamid at 6, 8 or 10 lb a.i./ac every spring for 3 years showed no cumulative adverse effect on cane growth or fruit production.

A warning is given of the need to assess crop tolerance in relation to the system of crop management practised. Damage which may be of little importance with one system of training the crop may well be unacceptable with another.

INTRODUCTION

The need to control perennial weeds has led to the evaluation of a wide range of herbicides in raspberry plantations in recent years. Band or spot treatment along the rows are the most common application techniques used for this type of weed problem, both for economic reasons and because of the sporadic nature of many perennial weed infestations. The risk of accidental overdosing is higher in these circumstances than with overall application. It is therefore particularly necessary to ensure that adequate safety margins are available for dosage rates likely to be recommended for effective weed control. The experiments reported in this paper examined crop tolerance to increasing application rates of a range of herbicides under weed-free conditions.

METHODS AND MATERIALS

The experiments were all carried out at Mylnefield on medium sandy clay loam soils with organic matter percentages (as determined by loss on ignition) of between 6 and 8%. Treatments were applied to mature raspberry plantations grown on the stool system. Expts. I & II were imposed on plantations which had hitherto been kept weed-free solely by cultivation. Expt. III was on an uncultivated plantation which had previously received annual applications of simazine at 2 lb a.i./ac. Plots consisted of single rows, with treatments applied to a one-foot band on each side of the row. Cane rows were 6ft apart and the alleys between the row bands were either rotary cultivated or flailed for weed and sucker control. The normal practice of removing suckers growing within the row between the stools during spring and early summer was not carried out in these experiments, so that the full effect of herbicide treatment on crop growth could be assessed. Canes growing between the stools were dug out and weak or broken canes in the stool were cut out when the spent fruiting canes were removed in late autumn. In late winter, the remaining canes were thinned to 6-8 per stool, tied-in and tipped. Records were taken of all cane growth removed from the plots.

Granular formulations of dichlobenil and chlorthiamid were diluted with sand and applied by hand. Other herbicides were applied by Mistifier knapsack sprayer using a single nozzle delivering 80 gal. water/treated acre. Plot rows were kept weed-free by handweeding throughout the experimental period to avoid any interaction between weeds and/or cultivation and the herbicide treatments. All herbicide applications were made just prior to the emergence of new cane in the spring.

RESULTS

Expt. I

Plot length was 20 ft, comprising 8 stools. The experiment was imposed on a 7-year old demonstration of cultivars. Cultivars were used as experimental blocks (Lloyd George, Malling Promise and Malling Jewel) to give three replications of each herbicide treatment. Control plots, of which there were three per block, were treated with a standard application of 2 lb a.i./ac simazine. Other herbicides were applied at up to three times the rates suggested by the manufacturers. Treatments and application rates of fluometuron, terbacil, bromacil, chlorthiamid and dichlobenil are shown in Table I.

Crop records taken on fruiting cane and new cane during the first growing season showed very large differences between the cultivars, but interaction between cultivar and herbicide treatment proved to be non-significant.

There were no significant differences between herbicide treatments in yield of fruit in the first season (Table I). New canes on plots treated with terbacil or bromacil showed a marked yellowing of foliage for several weeks, but Table I shows that there was no evidence of any check to growth on these or any of the other sprayed treatments. New canes within the stool area on plots treated with the granular herbicides dichlobenil and chlorthiamid were, however, shorter than those on other plots until late July. The mean height of new canes on June 5 was significantly less on these plots than on the control plots, and there was some indication of increasing effect with increasing dosage of chlorthiamid. By the end of the growing season, however, no differences between treatments in cane length within the stool could be detected.

A considerable reduction in cane production from between the stools was noted on plots treated with dichlobenil and chlorthiamid compared with control plots, and this was reflected in the significantly fewer canes dug out from the between-stool area on these plots (Table I). Average height of this cane was, however, not significantly reduced. None of the other herbicide treatments affected cane production between the stools. Despite the earlier evidence of cane suppression within the stool on plots treated with dichlobenil and chlorthiamid, there were no significant differences between herbicide treatments in numbers or average length of within-stool canes, either in those removed as unsuitable or surplus, or in those tied-in for fruiting.

The experiment was continued into the second year, without further herbicide treatment. The absence of differences between treatments in numbers and length of

Table I

Expt. I Fruit and cane records

Treatment (lb a.i./ac)		1st year fruiting records: Yield cwt/ac	1st year cane production records per plot: Young stool cane June 5 L.	Cane dug out No.	Cane dug out L.	Cane cut out No.	Cane cut out L.	Cane thinnings No.	Cane thinnings L.	Cane tied-in No.	Cane tied-in L.+	2nd year fruiting records: Yield cwt/ac
Control		58	16	89	20.	36	24	48	37	61	51	58
S.E. mean ±		2.8	0.5	7.9	0.6	4.3	0.8	3.9	0.8	1.9	0.6	2.5
Fluometuron	2.2	54	17	86	19	40	24	62	35	52	49	47
	4.4	62	17	99	21	36	24	50	34	62	53	61
	6.6	61	17	66	21	33	25	59	37	65	52	55
Terbacil	2.0	60	16	71	21	34	25	49	37	62	51	62
	4.0	54	18	105	21	48	25	63	38	61	50	52
	6.0	63	17	70	19	38	25	40	35	58	51	63
Bromacil	2.0	60	17	88	19	41	25	54	37	58	50	58
	4.0	65	17	68	22	30	24	62	37	59	51	59
	6.0	61	17	69	21	39	28	53	38	63	53	67
Chlorthiamid	8.3	55	14*	51*	18	40	22	50	34	56	49	50
	16.5	62	11***	37**	18	37	22	40	35	58	49	54
	24.8	72	8***	21***	18	39	24	40	36	59	49	62
Dichlobenil	8.3	62	12***	48*	20	33	23	46	37	59	49	58
	16.5	67	11***	28***	20	44	22	52	34	68	48	55
	24.8	63	11***	38**	18	56	24	57	34	62	50	53
S.E. mean ±		4.9	0.8	13.6	1.1	7.5	1.3	6.8	1.3	3.2	1.0	4.3

* , ** , *** significantly different from Control at the 5%, 1%, 0.1% level (respectively)

L. = Average length (in.)
\+ = before tipping

fruiting cane tied-in was reflected in a similar lack of differences in yield of fruit (Table I).

No visual evidence of initial treatment effects on new cane growth within or between the stools was noted during the second growing season. Records taken at cane removal at the end of the season showed no significant differences in numbers or average lengths of canes dug out between the stools, cut out within the stool, or left as potential fruiting cane for the following season.

Expt. II

Plot length was 40 ft, comprising 16 stools, in a 5-year-old plantation of cv. Malling Promise. Chlorthiamid was applied at 6, 8 and 10 lb a.i./ac either once only, two years running or three years running. There were three replications of each herbicide treatment and three untreated control plots per block. No other herbicide treatment was applied during the experiment and any weed growth was removed by hand-weeding. In Table II, the first season records are presented with years of application treated as extra replication, while in tables III and IV, herbicide application rates have been pooled to allow more detailed examination of the effects of repeated applications.

There were no adverse effects of herbicide treatment in the first season on yield of fruit (Table II). Production of new canes from between the stools was less on treated than on control plots, and some stunting of new cane in the stool was noted. Canes dug out from between the stools and weak canes cut out of the stools in October were bulked for recording purposes, so that the significant reduction in total cane numbers produced cannot be attributed directly to either category. Differences between treatments in numbers of canes retained as potential fruiting cane (>36 in. length) were not quite significant at the 5% level. By the time canes had been thinned and tied-in all evidence of treatment differences had disappeared. Average length of cane before tipping was unaffected by treatment. The lack of difference between treatments in canes tied-in was reflected in the second season's fruiting records regardless of whether re-treated or not. (Table III). Cane removal records again showed effects of the current season's treatment, but not of the original treatment, in numbers of canes dug out from between-stool areas. Records of within-stool cane, however, showed no evidence of damage from single or repeated treatments. In the third year there were no significant effects of repeated applications on fruit production or cane growth, when compared with the control treatment (Table IV). Comparison of total fruit yields over the period of the experiment showed no evidence of adverse cumulative effects of herbicide treatment.

Expt. III

Plot length was 12 ft, comprising 6 stools in a 4-year-old plantation of cv. Malling Jewel. Atrazine and simazine were applied at 1, 2, 4 & 8 lb a.i./ac to evaluate the tolerance of the crop to atrazine both in absolute terms and in relation to simazine as a standard. There were 4 replications of each treatment. Herbicide treatments were not applied in the second year and any weeds were removed by hand-weeding.

Records taken of yield of fruit and of the production of new cane showed no significant effects attributable to herbicide treatment (Table V). Nor were there any significant differences in fruit production in the second year.

DISCUSSION

Single applications of fluometuron, bromacil, terbacil and atrazine had no

Table II

Expt. II Year I - fruit and cane records

Treatment (lb a.i./ac)	Fruit yield cwt/ac	Total cane produced /plot No.	Stool cane >36 in. length No.	Cane tied-in No.	Cane tied-in L.+
Control	65	452	242	108	57
Chlorthiamid					
6	66	401	221	111	56
8	67	367**	204	109	57
10	67	333***	198	108	56
S.E. mean ±	2.7	18.4	16.1	1.8	1.1

Table III

Expt. II Year II - fruit and cane records

Treatment	Fruiting records	Cane production records per plot							
	Yield cwt/ac	Cane dug out		Cane cut out		Cane thinnings		Cane tied-in	
		No.	L.	No.	L.	No.	L.	No.	L+
Control	80	197	25	62	26	63	37	103	58
S.E. mean ±	2.8	11.1	0.6	6.3	0.7	5.1	0.9	3.2	0.5
Chlorthiamid once	79	165	27	67	26	80	38	106	57
S.E. mean ±	2.8	11.1	0.6	6.3	0.7	5.1	0.9	3.2	0.5
Chlorthiamid twice	77	158**	26	52	24	67	37	104	57
S.E. mean ±	2.0	7.9	0.4	4.4	0.5	3.6	0.6	2.3	0.4

* significantly different from Control at the 5% level
** significantly different from Control at the 1% level
*** significantly different from Control at the 0.1% level

L = average length (in.) + = before tipping

Table IV

Expt. II Year III - fruit and cane records

Treatment	Fruiting records: 3rd year yield cwt/ac	Fruiting records: Cumulative yield cwt/ac	Cane production records per plot: Cane dug out No.	Cane dug out L.	Cane cut out No.	Cane cut out L.	Cane tied-in No.	Cane tied-in L.+
Control	44	192	235	35	114	38	101	63
Chlorthiamid once	46	191	253	36	120	38	109	65
Chlorthiamid twice	46	187	291	35	108	38	110	64
Chlorthiamid thrice	45	192	246	35	123	37	100	62
S.E. mean ±	3.2	9.5	20.0	1.4	10.7	1.0	3.2	1.7

Table V

Expt. III - fruit and cane records

Treatment (lb a.i./ac)	1st year fruiting records: Yield cwt/ac	Cane production records per plot: Cane dug out No.	Cane dug out L.	Cane cut out No.	Cane cut out L.	Cane thinnings No.	Cane thinnings L.	Cane tied-in No.	Cane tied-in L+	2nd year fruiting records: Yield cwt/ac
Simazine 1	88	8	33	93	45	3	60	37	74	64
2	85	10	33	86	48	2	34	34	76	63
4	79	6	39	92	45	4	54	39	75	65
8	89	7	32	68	48	1	34	41	75	73
Atrazine 1	80	8	30	97	48	4	55	39	73	61
2	83	8	32	94	46	4	44	40	75	74
4	85	7	32	96	48	1	28	33	75	57
8	78	7	26	118	45	3	50	37	71	66
S.E. mean ±	5.4	1.5	3.2	14.0	1.9	1.2	12.3	2.4	1.6	4.3

L = average length (in.)   + = before tipping adverse effect on any aspect of crop growth either in the year of treatment or in the following growing season, despite the wide range of dosages applied. Results of other experiments with bromacil, terbacil and atrazine as single or repeated annual applications (Lawson & Rubens, 1970; Lawson & Waister, 1968) confirm the general safety of these herbicides on the established raspberry crop in Eastern Scotland, provided application is made before the emergence of new cane in early spring. Experiments on raspberries with fluometuron (Allott & Uprichard, 1970) in Northern Ireland showed no evidence of crop injury at 2 lb a.i./ac.

Regardless of the doses applied, the selective effects of chlorthiamid and dichlobenil on the different categories of cane growth were found only in the year of treatment and there was no indication of cumulative injury as a result of repeated applications of chlorthiamid. A reduction in between-stool cane numbers is relatively unimportant in the stool system of management. It could, however, be important in the hedge-row system where the grower depends on canes from root-buds for a proportion of his next season's fruiting cane. This may well be one of the factors contributing to the higher incidence of crop injury reported in hedge-row plantations in England, which had led to chlorthiamid being granted approval for use on raspberries only in Scotland (MAFF, 1972) and to dichlobenil being restricted to the "Scottish stool system" (Midox, 1969).

The stunting effect on early growth of stool-cane in these experiments was temporary. Lawson & Rubens (1970) also noted a temporary suppression of new cane growth in the stool following pre-emergence treatment with chlorthiamid and dichlobenil. Allen (1966) reported comparable results from trials with chlorthiamid in Scotland and England provided application was made before cane emergence, but when the new season's cane had already emerged by the date of herbicide application, cane suppression was much more severe. He did not, however, differentiate between new canes produced inside or outside the stool area. In a vigorous plantation where both cane numbers and average height are above the optimum for fruiting cane purposes, a certain amount of cane suppression by herbicides within the stool area may be tolerated for the sake of effective weed control. However, the effects of dichlobenil and chlorthiamid on different aspects of new cane growth emphasise the desirability of examining the reaction of the whole crop to herbicide treatment rather than simply that portion of it which is tied-in for subsequent fruiting. Otherwise important information on potential problems in less vigorous crops or those grown under different management systems may be missed.

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THE EFFECT OF REPEATED APPLICATIONS OF CHLORTHIAMID AND DICHLOBENIL ON BLACKCURRANTS AND RASPBERRIES

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Summary Doses of chlorthiamid and dichlobenil between 5.25 and 30 lb/a.i. per acre were applied to a blackcurrant plantation at four different times of the year for four years. High doses of both herbicides reduced the average crop yield. The reduction was greater with chlorthiamid than with dichlobenil.

When chlorthiamid and dichlobenil were applied to raspberries for seven years at four different times of the year chlorthiamid reduced crop yield in two years compared with dichlobenil. In one year both herbicides at 10 lb/ac reduced crop yield compared with applications at 5 lb/ac. In three years applications of both herbicides in May reduced crop yield compared with at other times.

INTRODUCTION

The herbicides chlorthiamid and dichlobenil have become widely used in recent years for the control of perennial weeds in bush and cane fruits. They are used most commonly early in the year and most published information has been from results of applications during this period. Chlorthiamid and dichlobenil can give effective control of weeds during other periods of the year. The experiments described here were laid down to test the tolerance of blackcurrants and raspberries to a range of doses of chlorthiamid and dichlobenil applied at four different times of the year and were continued for four and seven years respectively to determine if repeated applications during some periods of the year could affect crop yield.

METHODS AND MATERIALS

Experiment 1 - Blackcurrants

Blackcurrants, cultivar Baldwin, were planted as cuttings on 5th November 1965, 1 ft apart in rows 9 ft apart. Chlorthiamid and dichlobenil were applied annually to a band 1.5 ft wide on each side of the bush row in June or September or November or March between June 1966 and March 1971. Applications were timed as far as possible to coincide with moist soil conditions. Chlorthiamid was applied as 7.5% granules at 30, 21, 15, 10.5, 7.5 and 5.25 lb/ac, to plots 24 yds long, consisting of six subplots 4 yds long. Chlorthiamid was applied to the subplots at decreasing doses from the beginning of the main plot.

From June 1966 until September 1969 dichlobenil was applied as a 50% dispersible powder at 30-33 lb/ac by means of a logarithmic sprayer to plots 24 yds long. These plots were also divided into six subplots for recording purposes. As the average dose of dichlobenil per subplot approximated closely to the dose of chlorthiamid for the corresponding subplot, doses of chlorthiamid and dichlobenil were treated as being the same for statistical analysis. From November 1969 onwards dichlobenil was applied as 7.5% granules at the same doses and in a similar manner to the chlorthiamid. The treatments were replicated in two blocks. Herbicide rates are quoted throughout as active ingredient.

During 1966, 18% of the cuttings failed to establish. The missing bushes were replaced with two year old bushes in December 1967. The plantation received routine applications of simazine each year for the control of annual weeds and routine applications of fungicides and insecticides.

Experiment 2 - Raspberries

Raspberries, cultivar Malling Jewel, were planted on 31st October 1964, 1.5 ft apart in rows 6 ft apart. The plantation was maintained weed free until October 1965 by applications of simazine and paraquat and subsequently simazine was sprayed once each year for the control of annual weeds. Chlorthiamid and dichlobenil were applied annually to a band 3 ft wide on each side of the cane row in either October, December, March or May from October 1965 until May 1972. The applications were timed as far as possible to coincide with moist soil conditions. Chlorthiamid was applied at 7.5% granules at 5 and 10 lb/ac. Dichlobenil was applied at 5 and 10 lb/ac as 50% dispersible powder from October 1965 until May 1969 with either a Senior knapsack sprayer or an Azo-propane sprayer and from October 1969 until May 1972 as 7.5% granules. Plot size was a single row 20 ft long. The herbicide treatments were replicated three times in a randomised block design. Two untreated plots were included in each replication as control plots. Table 2 lists the times and rates of application.

Crop yield was recorded each year from 1966 until 1972. The number of young canes per plot was counted in 1966 and 1971.

RESULTS

Experiment 1 - Blackcurrants

No herbicide treatment had any effect on the growth or vigour of the bushes during the life of the plantation.

In 1968 crop yield was reduced by the two highest doses of herbicide compared with those at 5.25 lb/ac ($p = 0.01$) and 7.5 and 10.5 lb/ac ($p = 0.05$). Crop yield was also reduced by the highest dose of chlorthiamid compared with the highest dose of dichlobenil ($p = 0.05$) (Table 1).

In 1969 the different doses of dichlobenil had no effect on crop yield, but, as Table 1 shows, the highest dose of chlorthiamid again reduced crop yield compared with all doses of dichlobenil and the four lowest doses of chlorthiamid ($p = 0.05$). The second highest dose of chlorthiamid reduced crop yield compared with the three lowest doses of chlorthiamid and compared with dichlobenil at 21, 15 and 10.5 lb/ac ($p = 0.05$). In 1969 crop yield was reduced by the June application of dichlobenil compared with the June application of chlorthiamid ($p = 0.01$) but the September application of chlorthiamid reduced crop yield compared with the corresponding application of dichlobenil ($p = 0.01$). Applications of chlorthiamid in November and March also tended to reduce crop yield compared with applications of dichlobenil.

In 1970 the highest dose of both herbicides reduced crop yield compared with second highest dose ($p = 0.05$) and the four lowest doses ($p = 0.01$). The second highest dose reduced crop yield compared with the two lowest doses ($p = 0.01$).

In 1971 the highest dose of both herbicides reduced crop yield compared with the doses at 15, 10.5 and 7.5 lb/ac ($p = 0.01$) and 21 and 5.25 lb/ac ($p = 0.05$). Chlorthiamid reduced crop yield compared with dichlobenil ($p = 0.05$). There was also a time of application by herbicide interaction (p = 0.05). With the September, November and March applications the dichlobenil treated plots out-yielded the chlorthiamid treated plots but with the June application the chlorthiamid treated plots out-yielded the dichlobenil treated plots.

When total crop yield for all four years was analysed the highest dose of herbicide reduced crop yield compared with the second highest dose (p = 0.01) and the four lowest doses (p = 0.001). The second highest dose reduced crop yield compared with the doses at 15 and 5.25 lb/ac (p = 0.01) and 10.5 and 7.5 lb/ac (p = 0.001). There was also a significant interaction between herbicide and rate of application (p = 0.01). The three highest doses of dichlobenil out-yielded those of chlorthiamid (p = 0.05) but the two lowest doses of chlorthiamid out-yielded those of dichlobenil (p = 0.05). No other treatment had any significant effect on total crop yield.

Table 1

Effect of chlorthiamid and dichlobenil on crop yield of blackcurrants over four years

		Dose (lb/ac) and total crop yield (cwt/ac)							
Year	Herbicide*	30	21	15	10.5	7.5	5.25	Mean	S.E. of Mean (df = 47)
1968	D	6.9	5.0	7.5	6.8	6.7	8.6	6.9	
	C	1.9	4.1	7.4	9.6	9.5	11.3	7.3	± 0.73
1969	D	40.1	48.4	53.3	54.9	42.3	43.0	47.0	
	C	24.1	27.0	41.0	54.5	56.7	52.9	42.7	± 2.35
1970	D	26.1	36.8	40.3	44.4	42.7	42.9	38.8	
	C	24.9	30.8	41.4	34.9	53.7	59.6	40.9	± 1.69
1971	D	102.9	124.7	140.0	130.9	121.3	109.4	121.5	
	C	78.5	96.3	112.2	123.2	128.1	117.8	109.4	± 3.74
Mean	D	43.9	53.7	62.1	60.1	54.4	53.5	54.6	
	C	33.3	41.5	50.5	59.6	68.0	63.1	52.7	± 1.49

* D = dichlobenil C = chlorthiamid

Experiment 2 - Raspberries

During summer 1966 both dichlobenil and chlorthiamid at 10 lb/ac in May caused some stunting of the suckers. Later in the year the canes recovered and by the end of the year there was no obvious difference in cane size on any of the treated plots. The March applications of herbicide reduced the number of canes per plot compared with October (p = 0.01), December and May applications (p = 0.05). The higher dose of herbicide also reduced the number of canes per plot compared with the lower dose (p = 0.05). There was no difference between the overall effect of the two herbicides although there was a significant time of application by herbicide interaction (p = 0.05). With the March application chlorthiamid reduced the number of canes per plot compared with dichlobenil while with the May application the dichlobenil tended to reduce the number of canes per plot (Table 2).

As Table 3 shows crop yield in 1966 was higher from the March application of herbicides (treatments J, K, L, M,) than from the other application dates (p = 0.05). No other treatment had any significant effect on crop yield.

In 1967 the May applications of both herbicides at 10 lb/ac again caused slight stunting of the suckers. No damage occurred on the other plots and by autumn there was no apparent difference in cane growth between the plots.

In 1967 no treatment had any effect on crop yield although the May application of both herbicides at 10 lb/ac tended to reduce crop yield.

In 1968 chlorthiamid at 10 lb/ac in March and dichlobenil at 10 lb/ac in May caused a reduction in vigour of the suckers. The stunted canes recovered well during late summer.

In 1968 both herbicides at 10 lb/ac significantly reduced crop yield compared with the 5 lb/ac rate ($p = 0.01$).

During 1969 the treatments had no effect on the growth or vigour of the young canes. In 1969 no treatment had any significant effect on crop yield although there was a tendency for the higher dose of chlorthiamid to reduce crop yield compared with the lower dose.

In 1970 the March and May applications of herbicide caused more severe damage to the emerging canes than in previous years. The March treatments reduced the number of suckers emerging and caused stunting of the canes in May. Later in the season these canes recovered. The May treatments did not reduce the number of suckers emerging but caused reduced cane growth in June. In this case the check persisted until the end of the season.

Table 2

Effect of chlorthiamid and dichlobenil on cane production in raspberries, cv. Malling Jewel

Treatment No.	Month application	Herbicide	Dose lb/ac	No. canes/plot 1966	No. canes/plot 1971
A	-	-	-	102	124
B	October	dichlobenil	5	116	116
C	October	dichlobenil	10	87	110
D	October	chlorthiamid	5	109	99
E	October	chlorthiamid	10	96	90
F	December	dichlobenil	5	104	120
G	December	dichlobenil	10	91	116
H	December	chlorthiamid	5	83	96
I	December	chlorthiamid	10	96	81
J	March	dichlobenil	5	95	115
K	March	dichlobenil	10	88	105
L	March	chlorthiamid	5	68	122
M	March	chlorthiamid	10	68	83
N	May	dichlobenil	5	91	114
O	May	dichlobenil	10	81	108
P	May	chlorthiamid	5	105	105
Q	May	chlorthiamid	10	98	89
Dose mean 5 lb/ac				96	111
10 lb/ac				88	98
Sig. dif.				*	**
Herbicide mean dichlobenil				94	113
chlorthiamid				90	96
Sig. dif.				N.S.	***

In 1970 crop yield was higher on the plots treated with dichlobenil then on the plots treated with chlorthiamid (p = 0.05) (Table 3).

In 1971 March and May applications of both herbicides again caused stunting of the emerging canes. This stunting appeared in May with the March application and in June with the May application. The canes recovered during late summer and at the end of the growing season there was no apparent difference in the quality of the canes on the different plots. In 1971 chlorthiamid caused a significant reduction in the number of canes per plot compared with the dichlobenil (p = 0.001). The high dose of both herbicides reduced the number of canes per plot compared with the low dose (p = 0.01) (Table 2).

In 1971 the May application of both herbicides caused a significant reduction in crop yield compared with the October and March applications (p = 0.05). There was a tendency for the 10 lb/ac dose of herbicide to reduce crop yield compared with the 5 lb/ac dose. There was also a significant time of application by dose interaction (p = 0.05). With the October, December and May applications the plots treated with the low dose of herbicide outyielded the plots treated with the high dose, whereas with the March application (treatments J,K,L,M) the plots treated with the high dose outyielded the plots treated with the low dose.

Table 3

Effect of chlorthiamid and dichlobenil on crop yield of raspberries cv. Malling Jewel

Treatment No.		Crop yield (cwt/ac)							
		1966	1967	1968	1969	1970	1971	1972	Mean
A		6.2	31.9	95.6	82.3	112.1	88.3	87.4	72.0
B	D*	5.9	30.7	112.2	73.8	111.1	101.6	90.0	75.0
C	D	6.9	34.6	90.0	73.5	118.3	91.1	98.1	73.2
D	C	4.5	32.5	109.4	92.0	116.4	106.7	94.0	79.4
E	C	5.7	33.4	91.8	63.2	109.0	80.0	75.6	65.5
F	D	6.9	34.8	92.4	70.6	109.1	100.7	97.8	73.2
G	D	7.8	30.5	79.4	74.4	113.2	85.2	95.3	69.4
H	C	5.2	34.2	101.0	84.8	94.8	99.9	103.5	74.8
I	C	5.8	30.8	89.8	75.3	107.6	79.6	88.4	68.2
J	D	7.4	36.0	108.4	85.1	105.6	100.5	96.1	77.0
K	D	9.5	33.7	86.0	73.7	132.6	99.4	95.5	75.8
L	C	7.6	27.1	84.8	81.3	98.6	88.6	95.4	69.1
M	C	7.9	37.7	74.4	73.8	103.2	117.3	95.6	72.8
N	D	6.2	32.7	118.2	67.0	115.8	78.0	96.6	73.5
O	D	4.7	23.0	88.8	78.1	130.4	73.0	86.8	69.3
P	C	7.0	32.5	91.0	78.0	117.4	95.0	77.7	71.2
Q	C	6.3	22.6	103.0	66.0	105.5	77.4	73.5	64.9
Herbicide means									
Dichlobenil		6.9	32.0	96.9	74.5	117.0	91.2	94.5	73.3
Chlorthiamid		6.2	31.3	93.2	76.8	106.6	93.1	88.0	70.7
Sig. dif.		N.S.	N.S.	N.S.	N.S.	*	N.S.	*	-
Dose means									
5 lb		6.3	32.5	102.1	79.1	108.6	96.4	93.9	74.1
10 lb		6.8	30.8	87.9	72.2	115.0	87.9	88.5	69.9
Sig. dif.		N.S.	N.S.	**	N.S.	N.S.	N.S.	N.S.	-

* D = Dichlobenil C = Chlorthiamid

In 1972 the May applications of herbicide caused slight stunting of the raspberry canes. These canes made a good recovery later in the growing season.

In 1972 the dichlobenil treated plots outyielded the chlorthiamid treated plots (p = 0.05). The May applications of herbicide (treatments N,O,P,Q) reduced crop yield compared with the December and March applications.

DISCUSSION

The results of these trials show that, under Irish conditions, chlorthiamid is more toxic than dichlobenil to both blackcurrants and raspber ies during most periods of the year.

In three of the four years of the blackcurrant trial the highest doses of dichlobenil reduced crop yield while in all four years the two highest doses of chlorthiamid reduced crop yield. In all four years the two highest doses of dichlobenil outyielded the two highest doses of chlorthiamid, in two of the years significantly so. When total crop yield for all four years were analysed there was a highly significant reduction in crop yield caused by the three highest doses of chlorthiamid. These results are not in accord with previous results reported in England by Clay and McKone (1970) who obtained no such reductions in crop yield with similar doses of dichlobenil or with very much higher doses of chlorthiamid.

In the raspberry experiment chlorthiamid reduced crop yield significantly in the 5th and 7th years. This reduction was greater with the high dose of herbicide than with the low dose. In one of the two years in which cane numbers per plot were counted, the chlorthiamid treatments caused significantly greater reduction in the number of canes per plot.

These reductions in crop yield have not been reported previously, but chlorthiamid has been reported to have caused more severe marginal chlorosis in apples (Spencer - Jones and Wilson, 1970) and in gooseberries (Davison, 1970) than did similar doses of dichlobenil, indicating that chlorthiamid is a more potent herbicide than dichlobenil. Also Davison (1970) has reported that chlorthiamid gave better weed control than dichlobenil. The greater effectiveness of chlorthiamid may be associated with its greater persistence. However, on three occasions in these trials, summer applications of dichlobenil had a more deleterious effect on the crop than chlorthiamid. In 1968 the May application of dichlobenil caused stunting of the emerging raspberry canes while in 1969 and 1971 the June application of dichlobenil decreased crop yield of blackcurrants significantly compared with chlorthiamid. Thus, under certain conditions dichlobenil can be more harmful than chlorthiamid.

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PRONAMIDE FOR THE CONTROL OF GRASS, PERENNIAL AND ANNUAL WEEDS IN BLACKCURRANTS, GOOSEBERRIES, RASPBERRIES, APPLES AND PEARS

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Summary In 33 replicated trials and eight commercial observation trials in 1970-71 and 1971-72, pronamide at rates between 1.0 and 3.0 lbs a.i./ac has given consistently good control of *Agropyron repens* and other weeds when applied between November 1st to the end of February, to top fruit, bush and cane fruit in trials throughout England. There has been no crop damage to any of the crops, though new cane growth in raspberries may be slightly retarded at the highest application rate.

INTRODUCTION

Preliminary results reported by Sumpter (1970) showed good control of perennial weeds in soft and top fruit using pronamide. Further extensive investigations have been carried out on these crops over the past two years to evaluate weed control and crop tolerance. Results on strawberries are reported elsewhere in these proceedings by Clarke and Sumpter (1972).

METHOD AND MATERIALS

Pronamide was applied as a 50% w.p. (Kerb 50W) in 35-50 gal/ac. In comparative work terbacil was applied as an 80% w.p. at a rate of 0.8 lb a.i. per ac., bromacil as an 80% w.p. at 2.8 lb a.i. per acre, amino-triazole as Weedazol TL at 4 lb. a.i. per acre, and chlorthiamid as 7.5% granules at 7.5 lb. a.i. per acre. All applications were made using a Van de Weij gas sprayer or standard tractor mounted sprayer, using a standard pressure of 35 p.s.i. Trials were conducted in Kent, Essex, Norfolk and the West Midlands. There were 33 replicated plot trials, and eight commercial observation trials. Spray applications to raspberries and blackcurrants were applied to the base of the plants, those to gooseberries applied overall. Details of the varieties used, their age, soil type, number of replicates and dates of application are given in Table 1.

Assessments of crop vigour were made on a crop height and width, and on leaf and fruit characteristics where appropriate, using a 1-10 scale where 10 = untreated. Details of the effects of treatments on crop vigour and new cane development in raspberries are given in Table 2. Weed control results were assessed as the percentage present compared with untreated plots, and are given for 32 sites in Table 3. These weed control assessments were made just prior to harvest, except with top fruit, when they were made in early August. Earlier recordings are discussed in the results where appropriate.

Table 1

Crop, variety, application and site details

Site	Variety	Age of plants in yrs	No: of replicates	Application date	Soil type
Raspberries					
1	Malling Promise	6	2	8/11/71	Fine sandy loam
2	Malling Jewel	3	2	16/12/71	Fine sandy loam
3	N. Giant	4	2	9/12/71	Loamy sand
4	Malling Jewel	3	2	10/12/71	Sandy loam
5	N. Giant	5	2	13/12/71	Loamy sand
6	N. Giant	3	2	20/ 1/71	Clay loam
7	N. Giant	4	2	23/ 2/71	Loamy sand
Blackcurrants					
8	Baldwin	8	2	20/12/71	Sandy loam
9	"	5	3	3/ 1/72	Fine sandy loam
10	"	9	2	17/12/70	Clay loam
11	"	5	2	11/ 2/72	Fine sandy loam
12	"	6 (cut down in 1971)	2	17/ 2/72	Loamy sand
Gooseberries					
13	Leveller	5	2	14/12/71	Sandy loam
14	Careless	8	2	10/12/71	Sandy loam
15	"	6	4	24/11/71	Fine sandy loam
16	"	5	2	19/ 1/71	Clay loam
17	"	6	2	11/ 2/72	Loam
18	"	1	2	17/ 2/72	Clay loam
19	"	8	2	10/ 2/72	Sandy loam

Table 1 continued

Site	Variety	Age of plants in yrs	No: of replicates	Application date	Soil type
Apples					
20	R. Delicious	3	1	24/11/71	Fine sandy loam
21	Cox	7	1	9/11/71	Sandy clay loam
22	Cox	8	2	10/11/71	Clay loam
23	Grenadier and Cox	4	2	16/12/71	Fine sandy
24	Egremont Russet	5	2	26/11/71	Fine sandy loam
25	Cox	3	2	8/11/71	Loamy very fine sand
26	Cox	7	2	9/11/71	Sandy clay loam
27	Worcester P. and Cox	10	2	1/12/71	Loam
28	Worcester P. Laxton Superb	15	2	12/ 1/72	Sandy loam
29	Bramley	30	2	16/12/70	Clay loam
30	Cox	8	2	16/12/70	Clay loam
31	Cox	2	2	16/12/70	Sandy clay loam
Pears					
32	Dr.Joules Guyot	15	2	24/11/71	Fine sandy loam
33	Conference Comice	15 &	2	1/12/71	Loam

Table 2

Raspberries - crop vigour, and new cane development

Site	Treatment in lb /a.i./ac		New Canes Vigour	Height as % untreated
1	Pronamide	1.0	10	110.6
		1.5	10	98.0
		2.0	10	105.3
	Bromacil	2.4	10	98.0
	Untreated Control		10	100
2	Pronamide	1.0	10	95
		1.5	10	95
		2.0	10	95
		3.0	9.5	98.2
	Untreated Control		10	100
3	Pronamide	1.0	10	103
		1.5	10	101
		2.0	10	102
		3.0	10	95
	Untreated Control		10	100
5	Pronamide	1.5	10	109
		2.0	10	106
		3.0	10	96
	Untreated Control		10	100

Table 3

Control of *Agropyron repens* and other perennial grasses as % untreated

Treatment in lbs a.i./ac		Site number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Pronamide	1.0	50	87	70	-	-	70	-	97	-	-	95	-	80	50	45	-
	1.5	90	100	85	-	90	85	86	100	-	90	80	-	87	92	60	88
	2.0	95	100	97	-	89	90	88	100	-	95	-	-	96	93	75	96
	3.0	-	97	95	-	98	-	-	99	-	99	100	-	99	95	82	-
Bromacil	2.8	80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorthiamid	7.5	-	-	-	-	-	-	-	-	-	-	-	-	-	85	-	-
Hand weeded control		-	-	-	-	-	-	-	-	-	-	-	-	-	20	-	-

		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Pronamide	1.0	-	95	70	-	-	-	-	-	-	-	-	-	-	-	-	-
	1.5	-	90	90	90	90	55	87	80	-	89	88	65	93	90	87	87
	2.0	-	-	-	90	90	90	94	89	-	97	93	85	95	93	93	94
	3.0	-	100	90	-	-	-	-	95	-	-	-	-	-	-	-	-
Terbacil	0.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	93	-
Aminotriazole	4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	70

RESULTS

Table 3 shows that effective control of *Agropyron repens* was achieved at nearly all sites by 1.5 and 2.0 lbs a.i./ac. At only 5 out of 11 sites was the 1.0 lb rate effective (i.e. over 70%). The highest rate of application 3.0 lbs a.i./ac showed little improvement in weed control over 2.0 lb rate. In these trials, applications were made during the late autumn early winter period which seems to be the most effective time for application. There was a delay of between four and six weeks after treatment before any effect on perennial grasses was apparent. Their leaves then developed a bluish tinge, coincident with root kill, and this was soon followed by death of all top growth. No regrowth at any application rate was seen until the end of June, some four to six weeks later than areas treated with other comparative materials. The effect of pronamide is on the rhizome, especially the terminal and those near to it. Buds which do develope produce very weak growths which give very delayed emergence. *Agrostis stolonifera* and *Agrostis gigantea* were killed at all rates of pronamide. *Dactylis glomerata* is killed but large clumps do sometimes survive. All annual grasses were fully controlled.

Seedling docks of *Rumex crispus* and *Rumex obtusifolius* were killed at all rates of pronamide. Established docks were killed or severely retarded at rates of 1.5 lb a.i./ac and above, except at one site where no kill was noted. Reasons for the variation in dock control are not clear, though soil type may be of importance, the better kill being obtained on the lighter soils. Creeping buttercup, *Ranunculus repens* was controlled at all rates except 1.0 lb a.i./ac. All annual *Polygonum spp.*, including *Polygonum aviculare* were controlled at all rates. *Polygonum bistorta* was only partially susceptible, but it seems control can be given by applications in successive seasons.

Stellarea media was easily controlled, but *Gallium aparine* was not controlled at the lowest rate 1.0 lb a.i./ac. Weeds not controlled by any of the rates tested include *Taraxacum officinalis*, *Cirsium arvense*, *Trifolium repens*, and *Convolvulus arvensis*.

No injurous effects were noted to apples, pears, blackcurrants or gooseberries at any of the rates tested. Raspberries are tolerant of 2 lb a.i./ac., but as Table 2 shows a slight retardation in growth of new canes occurred at two sites at 3.0 lb a.i./ac. From all visual assessments apples and pears of the varieties tested showed no deleterious effects in terms of leaf and fruit quality and development, and no effect on fruit size and finish when compared with untreated. Careful note was taken of the growth of the young trees of Red Delicious and Cox tested.

In the gooseberry sites treated there were no problems noted by overall spraying. Where *Agropyron repens* was competing heavily with the bushes, control with pronamide resulted in a marked improvement in fruit size and overall yield.

There were no effects to fruit and leaf production following treatments to blackcurrants. The bushes tested were at least three years old, but at Site 12, the bushes were cut down four months before application.

The raspberry tests were all under English conditions. Scottish trials will be carried out in the coming season. No adverse effects were noted on the fruiting canes in terms of leaf or fruit production at any of the tested rates. Fruit size and colour was normal. Production of new canes was normal at up to 2 lb a.i./ac., except at Site 2 where the height, but not the number, was slightly reduced. A consistent small growth retardation was noted at 3.0 lb a.i./ac., but again this was in height and not number of new canes.

DISCUSSION

From these results, it would seem that effective control of *Agropyron repens* in these crops can be obtained at rates of 1.5 and 2.0 lb a.i./ac., when applied between November 1st and the end of February, with no adverse effects on the crops. Rates lower than 1.5 lb a.i./ac., can give good perennial grass control but are variable. At rates higher than 2.0 lb a.i./ac., the improvement is only marginal. There are several broad leaf weeds of importance in fruit plantations which are well controlled by pronamide at these rates.

Other crops not mentioned here which appear tolerant to pronamide but require further investigation include hops, blackberries, plums, redcurrants, loganberries, rhubarb and asparagus.

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THE RESPONSE OF VARIOUS FRUIT CROPS TO GLYPHOSATE

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Summary Overall sprays of glyphosate at concentrations from 0.28% to 2.24% were applied to apples, blackcurrants and raspberries in early March.

On apples, 0.28% and 0.56% sprays caused dormancy and leaf chlorosis of some shoot tips in spring but effects were slight. The number of lateral shoots on the leading shoot of the trees was increased by these treatments. 1.12% and 2.24% sprays were more damaging, reducing leaf expansion and shoot growth.

On blackcurrants, 0.28% spray caused little injury; injury from higher rates was more severe but regrowth was rapid.

On raspberries, 0.28% spray retarded fruit bud development temporarily. Higher rates caused increasingly severe effects on leaf growth on fruiting spurs and on sucker development.

Spraying of single shoots of apple or whole apple trees with 0.1% glyphosate at medium volume in summer resulted in dehiscence of apical leaves and dormancy of apices of many sprayed shoots. No effects were seen on unsprayed shoots. Low volume sprays with the same concentration to simulate drift caused little damage.

Painting of intact or cut stem bases of apple trees with 0.1% glyphosate produced no visible damage.

INTRODUCTION

The herbicidal properties of glyphosate* were first reported in 1971 (Baird et al, 1971). It is a foliage-acting herbicide which can be translocated to underground parts of herbaceous plants and has considerable herbicidal activity on annual weeds and on some herbaceous perennial weeds including *Agropyron repens* and *Cirsium arvense*. No crop/weed selectivity has yet been reported that allows overall application to crops but Baird et al, (1971) reported that applications to the bases of mature trees of a number of tree crops at doses up to 9 kg/ha caused no adverse effects. Present evidence suggests that glyphosate applied at 1 to 2 kg/ha will be of considerable use for weed control in British fruit growing for the control of both annual and perennial weeds. The herbicide could be used during crop dormancy to control weeds with foliage present in winter or as a directed spray in orchards during the growing season.

Dormant season treatments in bush and cane fruit and in tree fruit nurseries would be much more useful if overall treatment were possible as is recommended for

* N-(phosphonomethyl) glycine

paraquat on some fruit crops (Fryer and Makepeace, 1970). A preliminary experiment was therefore set up to observe the tolerance of apple, blackcurrant and raspberry plants to overall application of glyphosate in the dormant season. Since the herbicide will also probably be used during the growing season as a directed spray and because it can be translocated, it is important to know the extent of injury that could result from spraying the foliage of low growing branches or from spray drift. Additionally the possibility of damage from uptake through the bark of young trees or through wounds at the trunk base needs examination. These aspects were investigated in two experiments during the summer. The experiments were intended as a preliminary to more detailed work on crop tolerance and though further information will be gained from later assessments, an early account of the major effects of this herbicide was thought desirable.

METHODS AND MATERIALS

Experiment 1 The effect of overall applications of glyphosate in early March on apples, blackcurrants and raspberries.

The plant material used consisted of maiden trees of apple, cv. Cox's Orange Pippin on M26, one year old blackcurrant bushes cv. Baldwin and single raspberry canes with roots, cv. Malling Jewel. The apple trees and raspberry canes were sprayed prior to potting up in compost, the blackcurrants were potted up in 25 cm diam. plastic pots a few days before spraying. The plants were sprayed on 1.3.72; at the time of spraying the apple trees were dormant, the blackcurrant buds at the shoot apices were bursting and the raspberry buds were showing the first signs of growth. Two apple, three blackcurrant and three raspberry plants were sprayed at each herbicide rate.

The herbicide was applied using a laboratory pot sprayer with an 8002 T-jet operating at 2.1 kg/cm^2. Apples and raspberries (with roots enclosed in polythene bags) were laid horizontally in the spray chamber and the blackcurrants stood upright, the average distance below the spray nozzle being 40 cm. Two runs at each spray concentration were made over the plants. To simulate spray from both sides the apple and raspberry plants were turned through 180° between the two runs. The herbicide formulation used in all the experiments was the isopropylamine salt of glyphosate as an aqueous concentrate with added wetter (code number MON-2139). Concentrations of 0.28%, 0.56%, 1.12% and 2.24% were applied; with an estimated volume rate of 150 l/ha at target level the approximate amount applied per unit area for the lowest dose would be 0.5 kg/ha.

The apple and raspberry plants were potted up after spraying and to avoid rain affecting the treatment all the plants were kept in an unheated potting shed for 5 days before standing outside. Routine pesticide applications were made throughout the growing season. Assessments of injury from herbicide treatments were made at intervals.

Experiment 2 The effect of summer foliar applications of glyphosate to apple shoots.

Two year old trees of apple cv. Cox's Orange Pippin grown in pots of sand were used. At the time of spraying the shoots on all the trees were actively growing.

Spraying of part or whole of the trees was carried out on 4.7.72. using a laboratory pot sprayer. Where the whole shoot system was sprayed the pot was enclosed in a polythene bag. Where a single shoot was sprayed only the distal 55 to 65 cm was placed through the doors of the spray chamber. Glyphosate at 0.1% was sprayed at 2.1 kg/cm^2 pressure to single shoots or whole shoot systems as detailed in Table 1. Medium volume sprays were applied through an 8006 T-jet which gave

510 l/ha at the average target height for one spray run. Low volume sprays to simulate drift were through a 73039 T-jet at a volume rate of 55 l/ha. Two trees were sprayed in each treatment. Trees used for treatments 1 to 3 were on M2 rootstocks, trees for treatments 4 to 6 were on MM 106. Where three low volume applications were made these were at 30 second intervals. No run off of spray from leaves or down the stems was observed. Trees in treatments 2 to 8 were left under cover in a glasshouse after spraying. When put back outside, polythene was taped onto the stem bases and fastened over the pot edge to prevent herbicide being washed into the root zone. Visual assessment of injury from the herbicide treatments was made at intervals.

Table 1

Treatment of apple shoots with 0.1% glyphosate

	Spray volume	Tree area sprayed	No. of applications	Period under cover (h)
1	Medium	1 shoot	1	0
2	Medium	1 shoot	1	72
3	Medium	Whole tree	1	16
4	Low	1 shoot	1	16
5	Low	1 shoot	3	16
6	Low	Whole tree	1	16
7	Untreated control			16
8	Untreated control			72

Experiment 3 The effect of summer applications of glyphosate to intact and cut stem bases of apple trees.

Two year old apple trees cv. Cox's Orange Pippin on M2 rootstocks growing in containers of sand were used. At the time of treatment stem base diameter was about 3 cm and growth was vigorous. Treatment with 0.1% glyphosate solution on the stem below the stock and scion union was carried out on 17.7.72 as follows:

1. Painted onto the whole circumference of a 10 cm length of intact stem from 5-15 cm above sand level.
2. Painted onto a 3 x 1 cm vertical cut made 17 days before treatment 10 cm above sand level.
3. Painted onto a similar cut made immediately before treatment.

Each treatment was carried out on two trees in sunny dry weather. Paper towelling was placed below the painted area to catch any surplus solution but removed after treatment. The cuts were made such that a 1 to 2 mm thickness of wood was removed over most of the area. The bark at the edges of the 17 day-old cut was swelling when treated. Some hours after treatment polythene was taped onto the trees from above the treated area and fastened over the pot edge to prevent rain removing the herbicide. The polythene was removed after 10 days.

Visual assessments of injury from the herbicide treatments were made at intervals. Scores for degree of injury were made on the following 0 to 7 scale.

0 = plant dead

1 = moribund but not all tissue dead

2 = alive with some green tissue but unlikely to make further growth

3 = very stunted but still making growth

4 = considerable inhibition of growth

5 = readily distinguishable inhibition of growth

6 = some detectable adverse effect

7 = indistinguishable from control

RESULTS

Experiment 1 Apples. Assessments of degree of injury and shoot growth are shown in Table 2. Two months after bud burst, leaves at the tip of shoots treated with the two lower rates were chlorotic. At the 1.12% rate bud development was inhibited and leaves were chlorotic. Many leaves at shoot tips had elongated but remained narrow, the lamina failing to grow out. At the highest rate many shoot tips were dead or dormant with peeling of the cork layer and swelling and cracking of the distal parts of stems. This may have been associated with infection with apple canker (*Nectria galligena*).

Table 2

The effect of glyphosate sprayed on dormant apple trees 2, 4 and 6 months after treatment

	2 months	4 months			6 months
Glyphosate concentration (%)	Vigour score (0-7)	Vigour score (0-7)	No. of dormant shoots per tree	No. of lateral shoots at apex per tree+	No. of apical shoots per tree*
0	7.0	7.0	0.5	3.5	0
0.28	6.0	6.0	0.3	6.5	8.0
0.56	6.0	6.0	1.5	6.5	7.0
1.12	4.0	4.0	5.0	2.0	6.0
2.24	1.5	2.5	13.0	0	6.5

+ Number of lateral shoots arising from terminal 10 cm of old stem.

* Count of number of shoots > 5 cm long growing out from main stem 1 m above soil level.

When assessed after 4 months the most obvious effect of the two lowest rates was an increase in the number of lateral shoots growing out from the leading shoot. Occasional lower shoot tips were dormant and development of leaves from buds behind the tips was restricted. The effect on leaf growth was more apparent at the 1.12% rate; leaves from buds at old shoot apices had not developed normally and showed the characteristic narrowed shape. At the highest rate, leaf growth was severely restricted and many shoots were dying back.

After 6 months the effect of the lower rates on the number of lateral shoots at the top of the tree was again pronounced. At the two highest rates malformed leaves were still developing from buds below dormant shoot tips, but regrowth from other parts of the tree had become normal and vigorous.

Blackcurrants - As the plants commenced growth in the spring the lowest rate of glyphosate caused slight yellowing of occasional leaves and marginal and interveinal necrosis of some leaves from apical buds. At higher rates, symptoms became progressively more severe, affecting buds lower down the shoots. Shoot tips died back progressively and leaves often became necrotic. An assessment of the effects of the treatments is given in Table 3. There was no apparent effect on flower morphology but flowering was delayed on more severely affected bushes (0.56% treatment and above). Although initial effects were severe the plants in all treatments soon began to grow vigorously. There was no sign of leaf injury 4 months after treatment although dieback was continuing on one or two shoots at the highest rate.

Table 3

The effect of glyphosate sprayed on 1.3.72 on blackcurrant (B) and raspberry (R) assessed 2 and 4 months after treatment

Glyphosate Concentration (%)	2 months Vigour score (0-7) B	2 months Vigour score (0-7) R	4 months Vigour score B	4 months Vigour score R	4 months No. of dead shoot tips per bush B	4 months Length of stem dieback (cm) per bush B
0	7.0	7.0	7.0	7.0	0	0
0.28	6.0	4.3	6.7	5.0	0.3	0.2
0.56	5.0	3.0	6.0	5.0	1.0	6.6
1.12	4.0	1.0	5.0	2.7	2.0	15.7
2.24	3.0	1.0	4.7	1.3	3.0	41.7

Raspberries - All rates of glyphosate retarded growth of the fruiting canes or inhibited it completely. Two months after treatment, when 60% of the buds on the untreated canes had grown out with two to three leaves, many buds in the 0.28% treatment were retarded, the leaf mid-ribs were growing but the leaf laminae had not expanded. At the 0.56% rate most buds had burst but the growth of leaf laminae was inhibited. The vestigial leaves were chlorotic and red in colour. At the higher rates buds were either dormant or if just bursting were very chlorotic. Assessments of crop injury are given in Table 3.

Four months after treatment leaf deformity was still visible on all treatments except the lowest rate and even at this rate leaf development had been retarded. At the highest rates many buds were still only just bursting and were intensely red in colour. Characteristic leaf inhibition and chlorosis were also seen on suckers arising from roots of canes treated with 1.12% glyphosate or more. Once they had reached the soil surface they made little further growth. No abnormalities of flowers or fruit were observed on any treatment at any stage.

Later assessment of the response of the crop was abandoned because of an attack of spur blight (*Didymella applanata*) which killed off fruiting canes in some of the lower glyphosate rates.

Experiment 2

The effects of medium volume treatments of single shoots and whole shoot systems were similar. After 2 weeks the two or three youngest expanded leaves were showing marginal scorch of the proximal half of leaves and the expanding leaves were slightly chlorotic and incurled. During the next two weeks all these affected leaves fell and most shoots became dormant. No injury was seen on older expanded leaves of sprayed shoots or on shoot tips of unsprayed branches. When assessed 6 weeks after spraying many treated shoots were dormant; where sprayed shoots were still growing leaves were not expanding fully but remained small with narrow laminae. On many shoots on trees which had received the overall medium volume spray a number of lateral buds just below the dormant terminal bud were growing out.

The effects of the low volume treatments were very slight and were not detectable 6 weeks after treatment. Slight chlorosis and incurling of expanding leaves was noticed 2 weeks after spraying on those shoots which had been nearest the sprayer. Treated shoots did not become dormant and there did not appear to be any effects from translocation of herbicide to unsprayed shoots.

Experiment 3

Application of glyphosate to the stem bases of apple trees produced no visible effects on leaf colour or on shoot development up to 6 weeks after treatment and vigorous growth was maintained.

DISCUSSION

The results of the overall treatment of dormant apples suggest that the rates of glyphosate likely to be used for weed control are unlikely to cause much damage, so that strictly directed treatments may not be necessary. Since the treatments were given right at the end of the dormant period and at least a week elapsed between the application and the first rainfall, the possibility of damage should have been at a maximum. Higher rates showed increasingly severe injury indicating either that the bud scales or bark did not give complete protection from entry, or that the herbicide persisted until bud growth commenced. It does show that overall spraying with excessive doses on dormant shoots can be very damaging. Even the lowest rates induced the development of lateral buds (Table 2) which indicates that overall sprays could interfere with normal tree development. While such effects are generally undesirable there may be some circumstances where such growth regulating effects, if reproducible, could be useful, e.g. in containing vigorous extension growth, or altering tree form.

On blackcurrants the results indicate that spraying bush bases and perhaps overall spraying may be possible in winter. The result is surprising in view of the unprotected nature of blackcurrant buds and the severe injury that can be caused by overall sprays of paraquat in winter (Fryer and Makepeace, 1970). The crop appears to possess more tolerance or ability to recover than the other two crops in that regrowth was relatively fast even from the plants treated with the highest rate.

Raspberries appeared to be more severely affected than blackcurrant by overall applications of glyphosate in contrast to the relative effects of paraquat which is safe when applied to raspberry canes in winter (Min. Ag. Fish and Food, 1971). The fact that the buds had just commenced growth may have affected their susceptibility. The severity of the effects from the higher rates was shown by the long-term inhibition of bud growth and the occurrence of distorted leaves on suckers later in the year. As glyphosate is regarded as being inactivated rapidly in soil the effect on suckers must result from translocation of the herbicide to buds on the roots as with many perennial weeds (Baird et al, 1971).

The preliminary results of the treatments to apple shoots in the growing season suggest that the use of glyphosate in orchards in summer may not be too hazardous. Long term assessments on growth and flowering are necessary, since some translocated herbicides persist and produce effects 1 or 2 years after treatment (Clay and Ivens, 1968). These interim results do suggest however that damage from direct spraying of branches may be confined to the apex of the sprayed shoots and that there should be little or no harmful effect from small amounts of spray drift. The degree of effect should not have been reduced by climatic conditions since no rain fell for 4 days after treatment. Retaining trees in warmer dryer conditions after treatment did not appear to have led to any difference in response. The possibility of effects arising from root uptake would appear to be ruled out since precautions against this were taken and other work at WRO has shown that much larger amounts than were present on treated single shoots or stems would be needed to enter the root zone to give any effects on the trees.

The absence of short term effects from treatment of stem bases confirms the results of Baird et al, (1971) on the safety of stem treatment in spring. In addition the absence of effects from the cut stem treatments and the fact that it has no soil activity suggests that glyphosate should be safe to use as a directed spray under apples even where the trunks are sprayed. Since stem treatment with translocated herbicides can produce effects on shoots that do not show until a year after treatment (Davison and Clay, 1970) a final assessment of the safety of the treatments must be made later.

The final results of all three experiments have yet to be assessed but the type of response to high doses in the dormant season and to exposure of different parts of apple trees in the growing season suggest that glyphosate could be used without risk of unacceptable crop damage in some dormant and growing fruit crops. Further work will be needed to test the effect of spraying at different times in the dormant season, the effects of environmental conditions on responses in the growing season, the response of other cultivars and crops and more detailed studies of the effects of the herbicide on growth and crop production.

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