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The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION FOR SF 91

We declare that this work was done under my supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

John Atwood

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GROWER SUMMARY

Headline

A range of herbicide products have been assessed for use in strawberry bed systems and the most successful have been identified.

Background and expected deliverables

The majority of strawberries produced in the UK are grown in plastic-mulched raised beds. The alleyways between beds can be difficult to keep weed-free, because of the lack of crop competition. Where the alleyway is treated rather than the crop, there is the potential for using less selective herbicides that would not be safe when used over the crop. This project aims to investigate the safety and efficacy of a range of herbicides for total weed control in the alleyway.

The increasingly common practices of both bed replanting and thinning of high density plantings results in gaps in the plastic-mulched beds and consequent weed control problems. The problems have been exacerbated by the loss of soil sterilants. The use of chemical weed control over plastic-mulched beds has the potential for significant cost saving compared with hand-weeding. This project investigates the safety of existing approved strawberry herbicides and novel products when used over beds and will check for residues in the fruit.

The recent loss of the contact herbicide paraquat from the UK market has reduced the options available for runner and weed control between strawberry beds. The introduction of the contact herbicide Shark (carfentrazone-ethyl) offers another alternative for contact weed and runner control. This project evaluates the efficacy of Shark for runner and weed control in strawberry bed alleyways compared with industry standards.

Summary of the project and main conclusions

A range of herbicides (Table 1) were applied on 2 May 2008 to the alleyways between plastic-mulched strawberry beds that were not currently planted, but had previously been used for strawberries.

Table 1. Residual herbicide treatments applied to strawberry alleyways

No.	***Product***	***Active ingredient***	***Product rate***	***Approval status (strawberries)***
1.	Untreated			
2.	Stomp 400SC + Flexidor 125	pendimethalin (400 g/L) + isoxaben (125 g/L)	3.3 L/ha + 2.0 L/ha	Label
3.	Ally SX	metsulfuron methyl (20% w/w)	0.03 kg/ha	Not approved
4.	Artist	flufenacet (24 % w/w)+ metribuzin (17.5 % w/w)	2.5 kg/ha	Not approved
5.	Calaris	terbuthylazine (330 g/L) + mesotrione (70 g/L)	1.5 L/ha	Not approved
6.	Chikara	flazasufuron (25% w/w)	0.2 kg/ha	Not approved
7.	Goal 2E	oxyfluorfen (2 g/L)	2.0 L/ha	Not approved
8.	Ronstar Liquid	oxadiazon (250 g/L)	4.0 L/ha	Not approved
9.	Sencorex WG	metribuzin (70% w/w)	1.0 kg/ha	Not approved
10.	Skirmish	terbuthylazine (420 g/L) + isoxaben (75 g/L)	1.0 L/ha	Not approved
11.	Sumimax	flumioxazin (300 g/L)	0.1 L/ha	Not approved

- No damage was noted in the crop planted subsequently into the beds.
- Chikara (flazasufuron), Sencorex WG (metribuzin) and Goal 2E (oxyfluorfen) gave the best control of the predominant weeds groundsel, American willowherb and sow-thistle.

A further range of herbicides were assessed for crop safety, chemical residues and weed control when applied to strawberries post-planting over the plastic-mulched beds. Residual herbicides (Table 2) were applied on 27 May 2009 to a waiting bed crop of cold stored Elsanta runners in full leaf but before flowering.

Table 2. Residual herbicide treatments applied to strawberry beds

No.	***Product***	***Active ingredient***	***Product rate***	***Approval status (strawberries)***
1.	Untreated			
2.	Devrinol	napropamide 450 g/L	5.0 L/ha	Label
3.	Dual Gold	s-metolachlor 960 g/L	1.6 L/ha	Not approved
4.	Goltix Flowable	metamitron 700 g/L	5.0 L/ha	Not approved pre-harvest
5.	Teridox	dimethachlor 500 g/L	3.0 L/ha	Not approved

- No phytotoxicity symptoms were seen but the vigour of Teridox (dimethachlor) -treated plants was slightly reduced and the yield was also slightly reduced.
- Goltix Flowable (metamitron) appeared to give the best weed control.

Contact herbicides (Table 3) were applied on 1 June 2008 to a waiting bed crop of cold stored Elsanta runners in full leaf but before flowering.

Table 3. Contact herbicide treatments applied to strawberry beds

No.	***Product***	***Active ingredient***	***Product rate***	***Approval status (strawberries)***
1.	Untreated			
2.	Beetup	phenmedipham 160 g/L	2.5 L/ha	Label
3.	Defy	prosulfocarb 800 g/L	5.0 L/ha	Not approved
4.	Dow Shield	clopyralid 200 g/L	0.5 L/ha	Label but not for maidens
5.	Goltix Flowable	metamitron 700 g/L	3.0 L/ha	Not approved pre-harvest

- Defy (prosulfocarb) caused unacceptable foliage and flower distortion and reduced yield. The plants subsequently recovered however.
- None of the other treatments caused phytotoxicity or loss of yield.

Residue samples were taken from treatments applied over the beds. The only residues found were 0.02 mg/kg metamitron from Goltix Flowable applied at the higher 5 L/ha rate. This is below the maximum residue level (MRL) for metamitron (0.1 mg/kg). Application 5 days later at 3 L/ha did not give rise to residues in the fruit.

Herbicide treatments (Table 4) were applied to runner and weed growth adjacent to the beds in the autumn.

Table 4. Contact herbicide treatments applied to the alleyway between strawberry beds

No.	***Product***	***Active ingredient***	***Product rate***	***Approval status (strawberries)***
1.	Untreated			
2.	Shark	carfentrazone-ethyl 60 g/L	0.8 L/ha	Not approved
3.	Shark	carfentrazone-ethyl 60 g/L	1.6 L/ha	Not approved
4.	Harvest	glufosinate-ammonium 150 g/L	5.0 L/ha	Label
5.	Reglone	diquat	2.0 L/ha	Label

- Shark (carfentrazone-ethyl) was much less effective than Harvest (glufosinate-ammonium) at controlling runners and left some weeds uncontrolled, particularly annual meadow grass.
- Because no runner translocation damage resulted from any of the treatments, it is not possible to say if Shark is safer for autumn use on non-cut runners than Harvest.
- For control of cleavers and nettles, Shark does have some advantages over Harvest, so tank mixtures with Harvest will be considered in the experiments to be carried out in 2009.

Financial benefits

Some of the most effective treatments tested, Dual Gold (s-metolachlor), Chikara (on soil grown crops) and Shark, require SOLAs before they can be adopted by growers. Therefore there is no financial benefit from these treatments at present.

A SOLA would be required to permit the use of Chikara on pathways between strawberry crops. For these crops, the benefit in improved weed control could be around 100hr/ha or £600/ha. Chikara is relatively expensive at £300 / ha compared with a standard treatment such as Stomp 400SC 3.3 L/ha + Flexidor 2.0 L/ha (£130 / ha) but the treated pathway area is typically 50% of the field area. Sencorex WG was slightly less effective than Chikara but much cheaper at around £40/ha for 1kg/ha.

For over-bed treatments, some growers already use Dow Shield (clopyralid) or approved phenmedipham products similar to Beetup. It is reassuring that so far, no residues have been found in the fruit following these treatments. Goltix (metamitron) shows some potential for use as a bed treatment. At present the specific off-label approval (SOLA) only covers post-harvest use, but with the impending withdrawal of Ramrod (propachlor), Goltix could provide a partial replacement for groundsel control in particular.

It is estimated that hand weeding costs could be up to £1,200/ha per weeding session (i.e. 3p per plant/hole @ 40,000 plants /ha). Typically a crop may require one further weeding session at a quicker rate of £600/ha (i.e. 1.5p per plant/hole) per year. The total cost could amount to £1,800/ha or 300 hr/ha @ £6 per hr including overheads.

Action points for growers

- When available, Dual Gold appears safe for use over strawberry beds and, subject to SOLA application could provide useful residual control of a range of weeds.
- Goltix was safe applied over strawberry beds. It is currently approved for use post-harvest and could provide a useful alternative to Ramrod for residual control of groundsel. A low level of residue was detected in the fruit when tested at the full rate pre-harvest – this use is not currently approved.
- Currently approved herbicides Dow Shield and Devrinol (napropamide) did not give rise to residues when applied post-planting, pre-flowering over the plastic-

mulched strawberry beds. Similarly Beetup did not give rise to residues. Beetup is not approved on strawberries but similar formulations of phenmedipham are approved.

- Chikara was the most effective total herbicide for weed control between strawberry beds. It is approved for use on land not intended to bear vegetation. For strawberry crops a SOLA would be required to allow use between plastic-mulched beds.
- Shark was not as effective as Harvest for the control of strawberry runners between beds, but it was more effective than Reglone (diquat). No damage was seen on the mother plants in early spring even though the runners were not cut when sprayed in the autumn.

SCIENCE SECTION

Introduction

Alleyway herbicides

The majority of strawberries produced in the UK are grown in plastic-mulched raised beds. The alleyways between beds can be difficult to keep weed free, because of the lack of crop competition. Seed germinated weeds are the major threat, in particular groundsel, redshank, knotgrass and American willowherb. At present the herbicide choice for between bed alleyways is limited to products with approval for use over the top of strawberry crops. Where the alleyway is treated rather than the crop, there is the potential for using less selective herbicides that would not be safe when used over the crop. This project will establish the safety and efficacy of a range of herbicides for total weed control in the alleyway.

Over-bed herbicides

The increasingly common practice of bed replanting, and thinning of high density plantings, results in gaps in the plastic-mulched beds and consequent weed control problems. The problems have been exacerbated by the loss of methyl bromide and the lack of soil sterilants offering residual weed control. The use of chemical weed control over plastic-mulched beds has the potential for significant cost saving compared with hand weeding. No trials to demonstrate efficacy and safety of over the bed application have been done in recent years. This project will establish the safety of existing approved strawberry herbicides and novel products when used over beds and provide an opportunity for indicative residue samples to be taken.

Runner control and alleyway contact herbicides

The recent loss of the contact herbicide paraquat from the UK market has reduced the options available for runner and weed control between strawberry beds. The recent introduction of the contact herbicide Shark (carfentrazone-ethyl) offers another alternative for contact weed and runner control. This project will evaluate Shark for runner and weed control in strawberry bed alleyways compared to industry standards.

Materials and methods

Four experiments were done in 2008:

1. Evaluation of non-selective residual herbicides for alleyway weed control between strawberry beds
2. Evaluation of selective residual herbicides applied over the crop foliage to strawberries grown in plastic-mulched raised beds.
3. Evaluation of selective contact herbicides applied over the crop foliage to strawberries grown in plastic-mulched raised beds.
4. Evaluation of non-selective contact herbicides for removal of runners and weed growth in alleyways between strawberry beds

1. Alleyway residual herbicides

Site details

Soil type, fine sandy loam. The soil nutrient indices were P (3), K (2+), Mg (3), pH 6.4.

Previous cropping

Winter wheat 2005. Plastic-mulched beds were made up autumn 2005. Cropped with strawberry cv. Elsanta 2006 – 2007. The strawberry crop was sprayed off with Roundup (glyphosate 360 g/L) 5 L/ha in autumn 2007. The beds were left *in situ* for replanting in 2008.

Crop details

Waiting bed strawberry cv. Elsanta runners were planted 14 May 2008, inter-planted with 15+ mm runners planted 21 May 2008. All plants were supplied by Hargreaves Plants, Holbeach, Lincs as cold stored plants. The plant spacing was 15 cm within row with two rows 30 cm apart on the bed.

Crop husbandry

Prior to application of the experimental treatments the alleyways were sprayed with Harvest (glufosinate-ammonium 150 g/L) 5 L/ha + Reglone (diquat 200 g/L) 2 L/ha.

Following planting, light sprinkler irrigation (3 mm every 30 minutes from 9.30 – 18.00 every day) was used to aid establishment for 3-4 weeks after planting.

Fertiliser application followed normal industry practice (typically 3 kg / ha N, 1.5 kg/ha P_2O_5, 6 kg/ha K_2O per week) applied by fertigation.

Normal crop husbandry pesticide applications were made to the crop mainly for disease control (see Appendix 5 for details)

Tunnel covers were put on for the harvesting period 11 July – 28 July.

Treatments

Treatments (Table 5) were applied 2 May 2008 to weed-free alleyways (before strawberry planting). All treatments were applied in 400 L/ha water at 2-bar pressure using a CO_2-pressurised Oxford Precision Sprayer with a 0.5m boom and F03-110 spray nozzles. Weather conditions at the time of treatment are detailed in appendix 6.

Experimental design

The experiment was laid out in a randomised complete block design with 10 treatments (Table 5) replicated three times (see Appendix 1 for layout). Plots dimensions were 1.6 m wide and 2.5 m long. Treatments were applied to the 0.5m wide un-cropped alleyway between plastic-mulched strawberry beds.

Assessments

Weed control was assessed on 2 July 2008 and 17 August 2008. On the first assessment, a 36 x 45cm quadrat was used, placed centrally within the plot and weed seedlings were counted within the quadrat area. On the second assessment percentage weed cover was estimated for the whole plot.

Plants were inspected on 25 May, 12 June and 1 July 2008 for signs of phytotoxicity arising from the herbicides applied to the adjacent pathway.

Table 5. Residual herbicide treatments applied to strawberry alleyways in Experiment 1

No.	***Product***	***Active ingredient***	***Product rate***	***Approval status (strawberries)***
1.	Untreated			
2.	Stomp 400SC + Flexidor 125	pendimethalin (400 g/L) + isoxaben (125 g/L)	3.3 L/ha + 2.0 L/ha	Label
3.	Ally SX	metsulfuron methyl (20% w/w)	0.03 kg/ha	Not approved
4.	Artist	flufenacet (24 % w/w)+ metribuzin (17.5 % w/w)	2.5 kg/ha	Not approved
5.	Calaris	terbuthylazine (330 g/L) + mesotrione (70 g/L)	1.5 L/ha	Not approved
6.	Chikara	flazasufuron (25% w/w)	0.2 kg/ha	Not approved
7.	Goal 2E	oxyfluorfen (2 g/L)	2.0 L/ha	Not approved
8.	Ronstar Liquid	oxadiazon (250 g/L)	4.0 L/ha	Not approved
9.	Sencorex WG	metribuzin (70% w/w)	1.0 kg/ha	Not approved
10.	Skirmish	terbuthylazine (420 g/L) + isoxaben (75 g/L)	1.0 L/ha	Not approved
11.	Sumimax	flumioxazin (300 g/L)	0.1 L/ha	Not approved

2. Over-bed residual herbicides

Site details, previous cropping, crop details and crop husbandry are all similar to Experiment 1.

Treatments

Treatments (Table 6) were applied on 27 May 2008 over the top of the strawberry beds. The runners had been planted 6 and 13 days earlier and at the time of spraying were in leaf but pre-flowering (Fig. 1). All treatments were applied in 400 L/ha water at 2-bar pressure using a CO_2-pressurised Oxford Precision Sprayer with a 1.0m boom and F03-110 spray nozzles. Weather conditions at the time of treatment are detailed in Appendix 6.

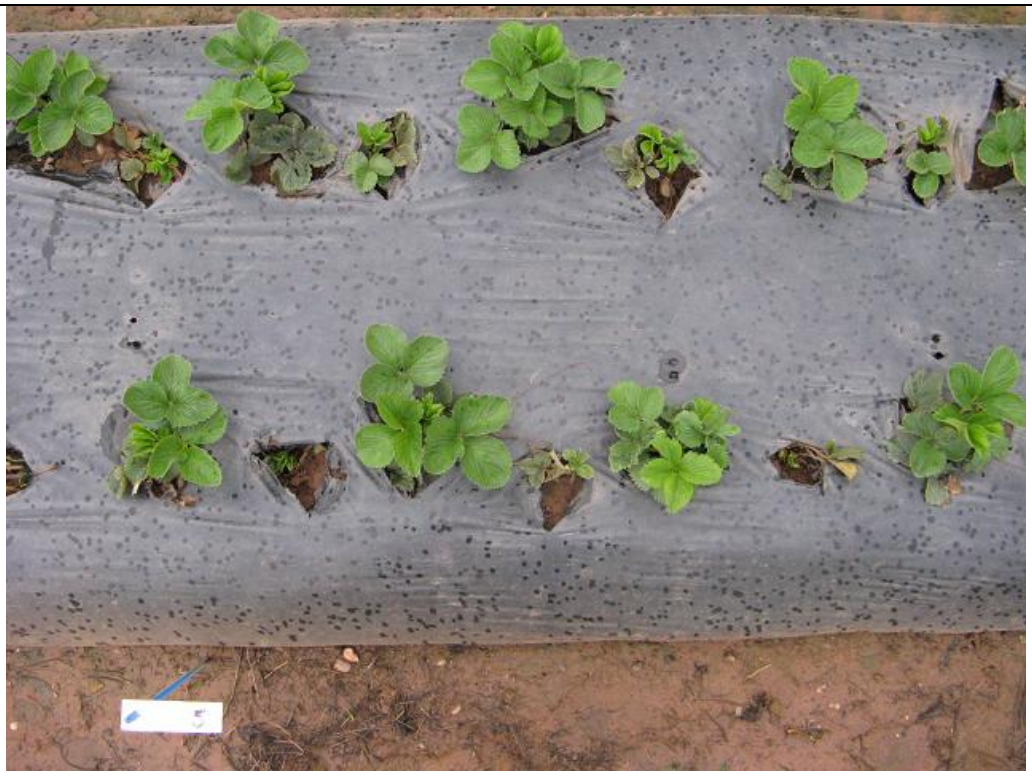

Figure 1. Plants on 25 May just prior to treatment. The larger plants are waiting bed plants, the smaller inter-plants are 15mm cold stored runners.

Table 7. Residual herbicide treatments applied to strawberry beds in Experiment 2

No.	***Product***	***Active ingredient***	***Product rate***	***Approval status (strawberries)***
1.	Untreated			
2.	Devrinol	napropamide 450 g/L	5.0 L/ha	Label
3.	Dual Gold	s-metolachlor 960 g/L	1.6 L/ha	Not approved
4.	Goltix Flowable	metamitron 700 g/L	5.0 L/ha	Not approved pre-harvest
5.	Teridox	dimethachlor 500 g/L	3.0 L/ha	Not approved

Experimental design

The experiment was laid out in a randomised complete block design with five treatments (Table 7) replicated four times (see Appendix 2 for layout). Plots

dimensions were 1.6 m wide and 2.5 m long. Treatments were applied to the central 0.8 m wide plastic-mulched strawberry bed as a 1 m wide spray swath.

Assessments

Weed control was assessed on 1 July 2008. No weed was present in the planting holes so an assessment was made of the weed cover in the bed shoulders as a 0 to 100 score compared with the untreated control (score 100). Plants were inspected on 25 May, June 12 and 1 July 2008 for signs of phytotoxicity arising from the herbicides. An assessment of plant vigour was made using a scoring system of 0 to 5.

Table 8. Scoring system for plant vigour and/or phytotoxicity

Score	% damage or loss of vigour
0	Complete kill – 80% damage
1	60 – 80% damage
2	40 – 60% damage
3	20 – 40% damage
4	5 – 20% damage or loss of vigour
5	No damage (as untreated controls)

Fruit samples were picked for residue analysis by QTS Analytical, East Malling, Kent, on 16 July at the start of commercial picking for the field.

An estimate of total fruit crop was made on 24 July by taking a once-over harvest on 10 plants (six waiting bed plants and four cold-stored runner plants), weighing all fruit, ripe and under-ripe including trusses. Weight of fruit picked earlier for residue analysis was added to the plot totals.

3. Over-bed contact herbicides

Site details, previous cropping, crop details and crop husbandry are all similar to Experiment 1.

Treatments

Treatments (Table 9) were applied on 1 June 2008 over the top of the strawberry beds. The runners had been planted 11 and 18 days earlier and at the time of

spraying were in leaf but pre-flowering. All treatments were applied in 400 L/ha water at 2-bar pressure using a CO_2-pressurised Oxford Precision Sprayer with a 1.0 m boom and F03-110 spray nozzles. Weather conditions at the time of treatment are detailed in Appendix 6.

Table 9. Contact herbicide treatments applied to strawberry beds in Experiment 3

No.	***Product***	***Active ingredient***	***Product rate***	***Approval status (strawberries)***
1.	Untreated			
2.	Beetup	phenmedipham 160 g/L	2.5 L/ha	Label
3.	Defy	prosulfocarb 800 g/L	5.0 L/ha	Not approved
4.	Dow Shield	clopyralid 200 g/L	0.5 L/ha	Label but not for maidens
5.	Goltix Flowable	metamitron 700 g/L	3.0 L/ha	Not approved pre-harvest

Experimental design

The experiment was laid out in a randomised complete block design with five treatments (Table 10) replicated four times (see Appendix 3 for layout). Plots dimensions were 1.6 m wide and 2.5 m long. Treatments were applied to the central 0.8m wide plastic-mulched strawberry bed as a 1m wide spray swath.

Assessments

Weed control was assessed on 1 July 2008. No weed was present in the planting holes so an assessment was made of the weed cover in the bed shoulders as a 0 to 100 score compared with the untreated control (score 100). Plants were inspected on 25 May, June 12 and 1 July 2008 for signs of phytotoxicity arising from the herbicides. An assessment of plant vigour was made using a scoring system of 0 to 5 (Table 8).

Fruit samples were taken for residue analysis on 16 July at the start of commercial picking for the field.

An estimate of total fruit crop was made on 26 July by taking a once-over harvest on 10 plants (six waiting bed plants and four cold-stored runner plants), weighing all fruit, ripe and under-ripe including trusses. Weight of fruit picked earlier for residue analysis was added to the plot totals.

4. Between-bed contact herbicides for alleyway runner and weed control

Site details, previous cropping, crop details and crop husbandry are all similar to Experiment 1.

Treatments

Treatments (Table 10) were applied on 25 September 2008 to the alleyways between strawberry beds which had an existing cover of strawberry runners and weed. All treatments were applied in 400 L/ha water at 2-bar pressure using a CO_2-pressurised Oxford Precision Sprayer with a 0.5 m boom and F03-110 spray nozzles. Weather conditions at the time of treatment are detailed in Appendix 6.

Table 10. Contact herbicide treatments applied to the alleyway between strawberry beds in Experiment 4

No.	***Product***	***Active ingredient***	***Product rate***	***Approval status (strawberries)***
1.	Untreated			
2.	Shark	carfentrazone-ethyl 60 g/L	0.8 L/ha	Not approved
3.	Shark	carfentrazone-ethyl 60 g/L	1.6 L/ha	Not approved
4.	Harvest	glufosinate-ammonium 150 g/L	5.0 L/ha	Label
5.	Reglone	diquat	2.0 L/ha	Label

Experimental design

The experiment was laid out in a randomised complete block design with five treatments (Table 10) replicated four times (see Appendix 4 for layout). Plots dimensions were 1.6 m wide and 2.5 m long. Treatments were applied as a 0.5m bands to the alleyway adjacent to the shoulder of plastic-mulched strawberry beds.

Assessments

Pre-treatment runner and weed levels were assessed on 26 September 2008 before any treatment effects would have been apparent. Post-treatment runner and weed assessments of percentage cover were made on 30 October 2008 and 14 February 2009.

Plants were inspected on 30 October 2008 and 14 February 2009 for signs of phytotoxicity arising from the herbicides.

Statistical analyses

Data from all experiments were analysed using analysis of variance (ANOVA). Where significant F ratios were obtained, means were separated using the least significant difference (L.S.D.) test.

Results and discussion

1. Alleyway residual herbicides

Weed control

The predominant weeds were groundsel (*Senecio vulgaris*) and willowherb (*Epilobium ciliatum*) with lower numbers of pineapple weed (*Matricaria discioides*) and sowthistle (*Sonchus oleraceus*). Annual meadow grass (*Poa annua*) germinated in some plots later. Some soil erosion occurred which may have affected weed control efficiency. All treatments reduced weed germination but differences were not statistically significant. However there were indications that Chikara, Goal 2E and Sencorex WG were the most effective treatments. Weed control from Stomp 400SC + Flexidor 125, Calaris, Ronstar Liquid and Skirmish were disappointing mainly due to poor control of groundsel. Ally and Skirmish failed to control of American willowherb. The industry standard Stomp 400SC + Flexidor 125 is known to give poor control of groundsel and American willowherb so these results are in line with previous findings. Skirmish has given variable control of groundsel in other trials results depend on the level of triazine resistance in the population. Ronstar Liquid normally has given better control of groundsel but may have been adversely affected by dry soil conditions.

Table 11. Weed seedling numbers per quadrat (0.16m^2) 2 July 2008 – alleyway herbicide experiment (Experiment 1)

	Treatment	Groundsel	Pineapple-weed	Sowthistle	Willowherb	Other	Total
1.	Untreated	10.0	1.3	1.7	1.0	3.3	17.3
2.	Stomp + Flexidor	8.0	0	1.3	1.0	0.3	10.7
3.	Ally SX	2.7	0.7	0.7	6.7	0.3	11.0
4.	Artist	6.3	0.3	0.7	1.3	0.7	9.3
5.	Calaris	7.0	0	3.3	1.0	0.3	11.7
6.	Chikara	3.0	0	0.7	0.3	0	4.0
7.	Goal 2E	7.0	0.7	0.7	0	0.3	4.7
8.	Ronstar Liquid	12.0	1.3	1.3	1.3	0.3	16.3
9.	Sencorex WG	3.0	0	1.7	1.0	0.3	6.0
10.	Skirmish	7.7	0.3	0.7	5.7	0	14.3
11.	Sumimax	6.0	0	1.3	0.3	0.7	8.3
	P (ANOVA)	0.666	0.262	0.765	0.252	**0.022**	0.241
	df	20	20	20	20	20	20
	S.E.D.	5.07	0.626	1.42	2.66	0.78	5.30
	L.S.D.	ns	ns	ns	ns	1.62	ns

ns = not significant

By the August assessment groundsel had flowered and senesced and sow thistle and annual meadow grass were more prevalent. Under these conditions the industry standard Stomp 400SC + Flexidor 125 and Skirmish performed much better (Table 12). Chikara and Sencorex WG continued to perform well (Figs. 3 and 4), but Goal 2E and Sumimax appeared to lack persistence and annual meadow grass developed in these plots (Fig. 5).

Figure 2. Untreated control

Figure 3. Chikara-treated alleyway.

Figure 4. Sencorex WG-treated alleyway

Figure 5. Sumimax-treated alleyway showing annual meadow grass

Table 12. Percentage weed cover 17 August 2008 – alleyway residual herbicide experiment (Experiment 1)

Treatment		**% weed cover**
1.	Untreated	47.0
2.	Stomp 400SC + Flexidor 125	6.7
3.	Ally SX	16.7
4.	Artist	18.3
5.	Calaris	11.7
6.	Chikara	5.7
7.	Goal 2E	15.0
8.	Ronstar Liquid	16.7
9.	Sencorex WG	7.3
10.	Skirmish	8.3
11.	Sumimax	11.7
	P (ANOVA)	0.106
	df	20
	S.E.D.	10.29

Phytotoxicity

No phytotoxicity was noted at any of the assessment dates

2. Over-bed residual herbicides

Weed control

No weeds developed in the planting holes but there was weed germination in the bed shoulders which was recorded (Table 13). The area recorded was at the edge of the herbicide-treated swath so it is possible that less than the full dose was applied and these results should therefore be treated with caution. The most effective treatment was Goltix Flowable.

Table 13. Mean weed cover score (0 – 100, 100 = most) on bed shoulders, assessed 1 July 2008, over-bed bed residual herbicide experiment (Experiment 2)

Treatment		Mean weed cover score
1.	Untreated	100.0
2.	Devrinol	75.7
3.	Dual Gold	91.9
4.	Goltix Flowable	40.5
5.	Teridox	86.5
	P (ANOVA)	<0.001
	df	12
	S.E.D.	9.95
	L.S.D.	21.66

Crop vigour and yield

There was a high degree of variability in the plant growth regardless of treatment. Consequently the untreated control scored less on average than the maximum score of 5. The Teridox and Dual Gold treatments did however appear to have a small reduction in vigour compared with the control however this was not statistically significant (Table 14).

Table 14. Mean crop vigour score (0 – 5, 5 = best), assessed 1 July 2008, over-bed bed residual herbicide experiment (Experiment 2)

Treatment		Mean score
1.	Untreated	4.38
2.	Devrinol	4.00
3.	Dual Gold	3.66
4.	Goltix Flowable	4.50
5.	Teridox	3.50
	P (ANOVA)	0.23
	df	12
	S.E.D.	0.299

Once-over harvest yield was recorded towards the end of commercial picking (Table 15).

Table 15, Once-over mean harvest yield (g) assessed 24 July 2008, over-bed bed residual herbicide experiment (Experiment 2)

Treatment		Weight/plant (g)
1.	Untreated	215.2
2.	Devrinol	241.3
3.	Dual Gold	212.4
4.	Goltix Flowable	223.2
5.	Teridox	195.1
	P (ANOVA)	0.309
	df	11
	S.E.D.	20.91

The Teridox treatment appeared to suffer a small yield reduction but the difference was not statistically different from the untreated control.

Residue analysis

No residues were detected from the Devrinol, Dual Gold or Teridox treatments. A small 0.02 mg/kg residue of metamitron was detected from the Goltix Flowable plot. The recorded residue is less that the MRL of 0.1 mg/kg.

3. Over-bed contact herbicides

Weed control

No weed developed in the planting holes but there was weed germination in the bed shoulders which was recorded (Table 16). The area recorded was at the edge of the herbicide treated swath so it is possible that less than the full dose was applied and these results should therefore be treated with caution. The most effective treatment was Goltix Flowable.

Table 16, Weed cover score (0 – 100, 100 = most) on bed shoulders, assessed 1 July 2008, over-bed bed contact herbicide experiment (Experiment 3)

Treatment		**Weed cover score**
1.	Untreated	100.0
2.	Beetup	81.8
3.	Defy	63.6
4.	Dow Shield	81.8
5.	Goltix Flowable	59.1
	P (ANOVA)	0.053
	df	12
	S.E.D.	12.96
	L.S.D.	28.27

Crop vigour and yield

There was a high degree of variability in the plant growth regardless of treatment. Consequently the untreated control scored less on average than the maximum score (5). The Defy treatment caused unacceptable leaf and flower distortion (Fig 6). The vigour score was reduced compared with the control (Table 17). No phytotoxicity or vigour loss was noted from any of the other treatments.

Table 17. Mean crop vigour score (0 – 5, 5 = best), assessed 1 July 2008, over-bed bed contact herbicide experiment (Experiment 3)

Treatment		**Score**
1.	Untreated	4.16
2.	Beetup	4.41
3.	Defy	2.75
4.	Dow Shield	4.09
5.	Goltix Flowable	4.25
	P (ANOVA)	<0.001
	df	12
	S.E.D.	0.267
	L.S.D.	0.572

Figure 6. Leaf and flower distortion caused by treatment with Defy

Once-over harvest yield was recorded towards the end of commercial picking (Table 18).

Table 18. Once-over mean harvest yield (g/plant) assessed 26 July 2008, over-bed bed contact herbicide experiment (Experiment 3)

Treatment		Weight/plant (g)
1.	Untreated	190.1
2.	Beetup	233.9
3.	Defy	132.5
4.	Dow Shield	272.8
5.	Goltix Flowable	230.4
	P (ANOVA)	<0.001
	df	12
	S.E.D.	18.97
	L.S.D.	41.34

Following foliar and flower damage (Fig. 6), the Defy treatment suffered a substantial yield reduction.

Residue analysis

No residues were detected from any of the treatments in this experiment. The Goltix Flowable was applied at a lower rate (3 L/ha) than in the residual experiment and although the application was made five days closer to harvest residues were not detected.

4. Alleyway contact herbicides

Weed and runner control

The most effective treatment for weed and runner control was Harvest (Table 19, Fig. 8). Shark was partially effective particularly at the higher (1.6 L/ha) rate (Fig. 9). Reglone and Shark at the lower (0.8 L/ha) were not sufficiently effective either for weed or runner control (Fig. 10). Where results were not statistically significant this was due to variability in the data.

The predominant weeds over the autumn period were annual meadow grass and American willowherb. Harvest controlled both species well. Shark controlled American willowherb but not annual meadow grass. Diquat failed to control either species completely. For future treatments, mixtures of Shark with Harvest should be considered, alongside higher rates of Shark.

Table 19. Weed and runner control assessed 30 October 2008 and 14 February 2009 (Experiment 4)

No.	Treatment	30 Oct 08			14 Feb 09
		% weed cover	% runner cover	% runner cover compared with pre- treated	% runner cover
1	Untreated control	42.5	37.5	118.8	13.8
2	Shark 0.8 L/ha	22.5	50.0	73.3	10.5
3	Shark 1.6 L/ha	13.5	25.2	36.4	4.8
4	Harvest 5.0 L/ha	0	5.0	25.0	1.2
5	Reglone 2.0 L/ha	12.5	15.0	37.5	8.8
	P (ANOVA)	<0.001	0.065	0.047	ns
	df	11	11	11	12
	S.E.D.	6.5	14.46	29.35	4.36
	L.S.D.	14.31	ns	64.60	ns

ns = not significant

Figure 7. Untreated runners and weed in alleyway.

Figure 8. Harvest controlled weed and runners completely

Figure 9. Shark did not completely control runners or annual meadow grass

Figure 10. Reglone failed to control runners or weed completely.

Phytotoxicity

No phytotoxicity was noted from any of the treatments when last recorded (14 February 2009). There was thought to be a possibility of herbicide translocation through runners when applied in the autumn without runner cutting. However no sign of this was seen in this trial. However the amount of runner cover was just under 40% in the control, it is possible that more damage could result from treatment of more extensive runner cover.

Effect on non-target organisms

No effect on non-target organisms was noted from any of the treatments in the four experiments conducted in this study.

Conclusions

1. Alleyway residual herbicides

Chikara, Sencorex and Goal 2E appeared to provide the best overall weed control for the alleyways. All provided good control of groundsel, American willowherb and sow thistle. These species are some of the most commonly found weeds in strawberry beds. Chikara has an approval for total weed control on non-cropped land and a SOLA would be required for alleyway use in strawberries. Sencorex is approved on potatoes and would also require a SOLA for use between strawberry beds. At present Goal 2E is not available in the UK and has been withdrawn from consideration for Annex 1 listing, so the future status for this product is uncertain.

2. Over-bed residual herbicides

One objective of this part of the project was to address concerns about residues that might arise from the use of herbicides over plastic-mulched beds. So far, the only residue that has been found has been from the use of full rate Goltix Flowable and the amounts were small, only 20% of the MRL. A further objective was to increase the range of herbicides available. This has become even more pressing as, since the start of the project, two further herbicides will be lost for strawberry production, Devrinol and Ramrod. Two new residual herbicides Dual Gold and Teridox show potential for selective use in strawberries although there was a slight loss of vigour from the use of Teridox. Neither is currently available in the UK and would require SOLA for use on strawberries. There are data available to support a SOLA for Dual Gold but Teridox is further from the UK market. In the meantime, Goltix Flowable appears safe and is currently has a SOLA for use after harvest. It is particularly useful for groundsel control. A SOLA would be required to enable its use pre-harvest.

3. Over-bed contact herbicides

Beetup, Dow Shield and Goltix Flowable (lower rate) treatments did not give rise to any fruit residues or crop damage. Formulations similar to Beetup and Dow Shield

are already approved for us in strawberries although the label for Dow Shield does not cover use on maidens. New treatment Defy proved to be too damaging to flowers and foliage and reduced yields. This treatment will not be used in 2009.

4. Alleyway contact herbicides

The new treatment, Shark, was not as effective at controlling runners or weeds as the industry standard Harvest. Because no runner translocation damage resulted from any of the treatments it is not possible to say if Shark is safer for autumn use on non-cut runners than Harvest. For control of cleavers and nettles Shark does have some advantages over Harvest, so tank mixtures with Harvest will be considered in the experiments to be carried out in 2009. Shark would require a SOLA for use in strawberries.

Technology transfer

There were no technology transfer activities during the first year of this project.

Appendix 1. Experiment 1 layout

Plot length 2.5m (including 0.5m untreated guard between plots), Plot width 1.5

Pathways	Beds	Pathways	Beds	Pathways
Plot 11 Trt 10		Plot 22 Trt 1		Plot 33 Trt 11
Plot 10 Trt 3		Plot 21 Trt 4		Plot 32 Trt 8
Plot 9 Trt 11		Plot 20 Trt 6		Plot 31 Trt 6
Plot 8 Trt 6		Plot 19 Trt 11		Plot 30 Trt 4
Plot 7 Trt 4		Plot 18 Trt 9		Plot 29 Trt 3
Plot 6 Trt 5		Plot 17 Trt 5		Plot 28 Trt 10
Plot 5 Trt 9		Plot 16 Trt 3		Plot 27 Trt 7
Plot 4 Trt 2		Plot 15 Trt 10		Plot 26 Trt 2
Plot 3 Trt 8		Plot 14 Trt 7		Plot 25 Trt 5
Plot 2 Trt 1		Plot 13 Trt 2		Plot 24 Trt 9
Plot 1 Trt 7		Plot 12 Trt 8		Plot 23 Trt 1

Experiment 1 layout continued

Trt	Chemical
1	Untreated
2	Stomp 3.3l/ha+ Flexidor 125 2.0 l/ha
3	Ally 0.03 kg/ha
4	Artist 2.5 kg/ha
5	Calaris 1.5 l/ha
6	Chikara 0.2 l/ha
7	Goal 2E 2.0 l/ha
8	Ronstar Liquid 4.0 l/ha
9	Sencorex WG 1.0 kg/ha
10	Skirmish 1.0 l/ha
11	Sumimax 0.1 l/ha

Appendix 2. Experiment 2 layout

Plot length 2.5m (including 0.5m untreated guard between plots), Plot width 1.5

	Beds	Path	Beds
	Plot 10 Trt 5		Plot 20 Trt 4
	Plot 9 Trt 1		Plot 19 Trt 5
	Plot 8 Trt 4		Plot 18 Trt 2
	Plot 7 Trt 3		Plot 17 Trt 1
REP 2	Plot 6 Trt 2	REP 4	Plot 16 Trt 3
	Plot 5 Trt 1		Plot 15 Trt 3
	Plot 4 Trt 4		Plot 14 Trt 1
	Plot 3 Trt 3		Plot 13 Trt 4
	Plot 2 Trt 5		Plot 12 Trt 2
REP 1	Plot 1 Trt 2	REP 3	Plot 11 Trt 5

Trt	Chemical
1	Untreated
2	Devrinol 5 l/ha
3	Dual Gold 1.6 l/ha
4	Goltix Flowable 5 l/ha
5	Teridox 3 l/ha

Appendix 3. Experiment 3 layout

Plot length 2.5m (including 0.5m untreated guard between plots), Plot width 1.5

	Beds	Path	Beds
	Plot 10 Trt 4		Plot 20 Trt 1
	Plot 9 Trt 1		Plot 19 Trt 2
	Plot 8 Trt 2		Plot 18 Trt 3
	Plot 7 Trt 5		Plot 17 Trt 4
	Plot 6 Trt 3		Plot 16 Trt 5
REP 2		REP 4	
	Plot 5 Trt 4		Plot 15 Trt 3
	Plot 4 Trt 2		Plot 14 Trt 1
	Plot 3 Trt 5		Plot 13 Trt 5
	Plot 2 Trt 3		Plot 12 Trt 4
	Plot 1 Trt 1		Plot 11 Trt 2
REP 1		REP 3	

Trt	Chemical
1	Untreated
2	Phenmedipham (Dancer) 2.5 l/ha
3	Defy 5 l/ha
4	Dow Shield 0.5 l/ha
5	Goltix 3.0 l/ha

Appendix 4. Experiment 4 layout

Plot length 2.0m (plus 0.5m untreated guard between plots), Plot width 1.5.

Treatments applied to 0.5m pathways between beds

	Pathways	Beds	Pathways
Rep 2	Plot 10 Trt 3	Rep 4	Plot 20 Trt 4
	Plot 9 Trt 1		Plot 19 Trt 1
	Plot 8 Trt 4		Plot 18 Trt 5
	Plot 7 Trt 2		Plot 17 Trt 3
	Plot 6 Trt 5		Plot 16 Trt 2
Rep 1	Plot 5 Trt 5	Rep 3	Plot 15 Trt 5
	Plot 4 Trt 3		Plot 14 Trt 1
	Plot 3 Trt 2		Plot 13 Trt 4
	Plot 2 Trt 4		Plot 12 Trt 3
	Plot 1 Trt 1		Plot 11 Trt 2

Trt	Chemical	Timing
1	Untreated	September
2	Shark 0.8 l/ha	September
3	Shark 1.6 l/ha	September
4	Harvest 5.0 l/ha	September
5	Reglone 2.0 l/ha	September

Appendix 5. Other pesticide applications

Crop husbandry pesticide applications

Date	Product	Active ingredients	Rate / ha
14/6/08	Rovral Flo	iprodione 255 g/L	6 L
	Thianosan	thiram 80% w/w	1 kg
	Fortress	quinoxyfen 500 g/L	0.25 L
	Maxicrop	fertiliser	2 L
23/6/08	Aliette	fosetyl-aluminium 80% w/w	3.75 kg
27/6/08	Frupica	mepanypyrim 450 g/L	0.9 L
	Nimrod	bupirimate 250 g/L	1.4 L
	Maxicrop	fertiliser	3 L
10/7/08	Switch	fludioxinil + cyprodenil 25+37.5% w/w	1 kg
	Sulphur	sulphur 80% w/w	1.6 kg
	Maxicrop	fertiliser	3 L

Appendix 6. Weather conditions at the time of spraying

Weather conditions at the time of spraying experiment 1.

Ground condition	Damp
General weather	Warm
Temperature	15-18^{o}C
Wind direction	Westerly – North Westerly
Wind speed	0 – 7 km/hr
Weather in previous 24hr	Showery, warm
Weather post application	Showery, warm
Drift	None

Weather conditions at the time of spraying experiment 2.

Ground condition	Wet
General weather	Cool
Temperature	13^{o}C
Wind direction	South Easterly
Wind speed	3-5 km/hr
Weather in previous 24hr	Wet, cool
Weather post application	Showery, warm
Drift	None

Weather conditions at the time of spraying experiment 3.

Ground condition	Damp
General weather	Overcast, cool
Temperature	13°C
Wind direction	None
Wind speed	None
Weather in previous 24hr	Dry, warm
Weather post application	Not noted
Drift	None

Weather conditions at the time of spraying experiment 4.

Ground condition	Dry
General weather	Overcast, warm
Temperature	19ºC
Wind direction	none
Wind speed	None
Weather in previous 24hr	Dry, warm
Weather post application	Not noted
Drift	None

Appendix 7. Temperature and rainfall data 10 days prior to and post treatment

Experiment 1 treated 2 May 2008

Date	Daily Temperature		Rainfall (mm)
	min	max	
22 April	4.3	29.9	
23 April	5.8	31.4	
24 April	5.8	23.7	
25 April	7.3	18.1	
26 April	6.2	23.7	6.0
27 April	8.0	31.4	
28 April	5.4	20.6	
29 April	3.1	19.5	
30 April	5.8	18.4	
1 May	5.4	24.1	
2 May	3.1	30.3	
3 May	6.9	29.2	
4 May	11.3	19.5	4.0
5 May	11.7	34.9	5.0
6 May	9.9	28.1	
7 May	9.1	32.6	
8 May	9.9	27.7	
9 May	11.3	34.5	
10 May	11.7	33.3	
11 May	13.1	33.7	
12 May	10.2	29.9	

Experiment 2 treated 27 May 2008

Date	Daily Temperature		Rainfall
	min	max	
17 May	9.9	13.1	1.2
18 May	6.2	21.3	0.2
19 May	3.9	18.8	0
20 May	3.5	22.7	0
21 May	5.4	25.5	0
22 May	7.7	18.8	0
23 May	10.6	15.6	0.4
24 May	10.2	20.6	1.8
25 May	8.4	13.1	15.2
26 May	9.9	15.3	16.8
27 May	9.5	14.9	19.2
28 May	11.3	17.4	10.2
29 May	9.9	35.7	0.2
30 May	12.8	24.5	0
31 May	13.1	26.6	0
1 June	13.5	18.8	0
2 June	12.8	22.3	12.8
3 June	13.8	19.1	4.8
4 June	9.5	36.9	0
5 June	10.2	34.5	0
6 June	10.6	33.3	0

Experiment 3 treated 1 June 2008

Date	Daily Temperature		Rainfall
	min	max	
23 May	10.6	15.6	0.4
24 May	10.2	20.6	1.8
25 May	8.4	13.1	15.2
26 May	9.9	15.3	16.8
27 May	9.5	14.9	19.2
28 May	11.3	17.4	10.2
29 May	9.9	35.7	0.2
30 May	12.8	24.5	0
31 May	13.1	26.6	0
1 June	13.5	18.8	0
2 June	12.8	22.3	12.8
3 June	13.8	19.1	4.8
4 June	9.5	36.9	0
5 June	10.2	34.5	0
6 June	10.6	33.3	0
7 June	9.5	24.1	0
8 June	10.6	42.4	0
9 June	12.8	44.6	0
10 June	14.2	39.4	0
11 June	12.8	36.1	6.4
12 June	12.0	27.7	0.4

Experiment 4 treated 25 September 2008

Date	Rainfall
16 September	0
17 September	0
18 September	0
19 September	0
20 September	0
21 September	0
22 September	1.4
23 September	0
24 September	0
25 September	0.2
26 September	0
27 September	0
28 September	0.2
29 September	1.8
30 September	1.2
31 September	0
1 October	0
2 October	0
3 October	0
4 October	0
5 October	0

Temperatures data was not available for this period due to the loss of a data logger