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Project leader:	John Atwood, ADAS UK Ltd.
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Some of 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 and SF 91a

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

Senior Horticultural Consultant

ADAS UK Ltd

Signature .....J Atwood..... Date .....9 July 2010.....

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GROWER SUMMARY

Headline

A range of herbicide products were assessed for use in strawberry bed systems and successful treatments were identified for use in alleyways, over beds and for runner control.

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 evaluated 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 fumigants. The use of chemical weed control over plastic-mulched beds has the potential for significant cost saving compared with hand-weeding. This project evaluated the safety of existing approved strawberry herbicides and novel products when used over beds.

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) was thought to offer another alternative for contact weed and runner control. This project evaluated the efficacy of Shark for runner and weed control in strawberry bed alleyways compared with industry standards. An extension to the project (SF 91a, also reported here) evaluated the potential for using Shark as an overall dormant season treatment to selectively clean up existing weeds in plastic mulched beds and in traditional matted-row plantings.

The expected deliverables from this project are:

- Information on the relative efficacy and crop safety of selected herbicides when used as alleyway or over-bed treatments for weed control during the growing season in strawberries.
- Information about the level of chemical residues in fruit resulting from over-bed herbicide application to strawberries grown in plastic mulched beds.

- Information on the relative efficacy and crop safety of Shark when used as a runner control treatment in the alleyways and as an overall dormant season treatment.

Summary of the project and main conclusions

Alleyway treatments

A range of herbicides (Table 1) were applied in the spring to the alleyways between previously used plastic-mulched strawberry beds that were not currently planted, but were subsequently planted after the alleyway spray application. Two experiments were carried out, with different sites used in 2008 and 2009.

Table 1. Residual herbicide treatments applied to strawberry alleyways

Product	***Active ingredient***	***Product rate***	***Approval status (strawberries)***
Stomp 400SC + Flexidor 125	pendimethalin (400 g/L) + isoxaben (125 g/L)	3.3 L/ha + 2.0 L/ha	Label
Ally SX	metsulfuron methyl (20% w/w)	0.03 kg/ha	Not approved
Artist	flufenacet (24 % w/w)+ metribuzin (17.5 % w/w)	2.5 kg/ha	Not approved
Calaris	terbuthylazine (330 g/L) + mesotrione (70 g/L)	1.5 L/ha	Not approved
Chikara	flazasufuron (25% w/w)	0.15-0.2 kg/ha	Not approved
Diuron 80WP	diuron (80% w/w)	1.25 kg/ha	Not approved
Goal 2E	oxyfluorfen (2 g/L)	2.0 L/ha	Not approved
Ronstar Liquid	oxadiazon (250 g/L)	4.0 L/ha	Not approved
Sencorex WG	metribuzin (70% w/w)	0.7-1.0 kg/ha	Not approved
Skirmish	terbuthylazine (420 g/L) +	1.0 L/ha	Not approved

	isoxaben (75 g/L)		
Springbok	dimethenamid-p (200 g/L) + metazachlor (200 g/L)	2.5 L/ha	Not approved
Sumimax	flumioxazine (300 g/L)	0.1 L/ha	Not approved

Goal 2E was only tested in 2008 and Diuron 80WP and Springbok were only tested in 2009. Where two rates are listed, the lower rate was used in 2009.

- Chikara and Sencorex WG gave the best control of the predominant weeds; annual meadow grass (*Poa annua)*, groundsel (*Senecio vulgaris*), American willowherb (*Epilobium ciliatum*) and sow-thistle (*Sonchus oleraceus*) and had good persistence.
- Ally SX performed well where groundsel and annual meadow grass predominated, but in 2008 failed to control American willowherb.
- Ronstar Liquid and Springbok were initially very effective on groundsel and annual meadow grass but were less persistent than Chikara, Sencorex WG or Ally SX.
- Artist, Calaris, Skirmish and Sumimax give significant levels of weed control but showed some weakness in groundsel control.
- No damage was noted in the crop planted subsequently into the adjacent beds.

Bed treatments

A further range of herbicides was assessed for crop safety, chemical residues and weed control when applied to strawberries post-planting over the plastic-mulched beds. Two sets of experiments were carried out over two years (four experiments in total). Residual herbicides (Table 2) were applied shortly after planting in May to 60-day crops planted as cold stored runners in early leaf. Contact herbicides (Table 3) were applied to similar crops but just before flowering. The experiments were carried out on different sites using the cultivars Elsanta (2008) or Sonata (2009).

- Goltix Flowable appeared to give the best weed control from results in 2008. A few leaves showed slight yellowing in 2009 but vigour and yield was not affected. There was insufficient weed germination in 2009 to further test the efficacy of the residual treatments.

- No foliar phytotoxicity symptoms were seen in 2008 although HDC H5 slightly reduced yields, but in 2009 Springbok and HDC H5 caused unacceptable stunting.

Table 2. Residual herbicide treatments applied to strawberry beds

Product	***Active ingredient***	***Product rate***	***Approval status (strawberries)***
Devrinol[1]	napropamide (450 g/L)	5.0 L/ha	Label
Dual Gold	s-metolachlor (960 g/L)	1.4-1.6 L/ha	SOLA 1389/10[3]
Goltix Flowable	metamitron (700 g/L)	5.0 L/ha	Not approved pre-harvest
Springbok[2]	dimethenamid-p (200 g/L) + metazachlor (200 g/L)	2.5 L/ha	Not approved
HDC H5	confidential (500 g/L)	3.0 L/ha	Not approved

[1]Devrinol was only tested in 2008
[2]Springbok was only tested in 2009.
[3]SOLA 1389/10 allows for 2 applications of Dual Gold at 0.7 L/ha to be made.

Table 3. Contact herbicide treatments applied to strawberry beds

Product	***Active ingredient***	***Product rate***	***Approval status (strawberries)***
Alpha phenmedipham 320	phenmedipham (320 g/L)	1.25 L/ha	Label
Beetup	phenmedipham (160 g/L)	2.5 L/ha	Label
Defy	prosulfocarb (800 g/L)	5.0 L/ha	Not approved
Dow Shield	clopyralid (200 g/L)	0.5 L/ha	Label but not for maidens
Goltix Flowable	metamitron (700 g/L)	3.0 L/ha	Not approved pre-harvest
Alpha phenmedipham 320 + Goltix Flowable	phenmedipham (320 g/L) + metamitron (700 g/L)	1.25 L/ha + 3.0 L/ha	Label Not approved pre-harvest

Beetup was replaced with Alpha phenmedipham 320 in 2009, Defy was only tested in 2008 and the tank mixture of Alpha phenmedipham 320 + Goltix Flowable was only tested in 2009.

- Defy caused unacceptable foliage and flower distortion and reduced yield. The plants did subsequently recover to some extent.

- The Alpha phenmedipham 320 + Goltix Flowable tank mix caused some foliar yellowing and stunting.
- None of the other treatments caused phytotoxicity or loss of yield.
- The only residues found were 0.02 mg/kg metamitron (below the MRL of 0.1 mg/kg) from Goltix Flowable applied at the higher 5 L/ha rate in 2008. No residues were found in 2009.
- There was insufficient weed germination to test the efficacy of the post emergence treatments.

Runner and alleyway treatments

In an assessment of runner and alleyway weed control, herbicide treatments (Tables 4 and 5) were applied to runner and weed growth adjacent to the beds in the autumn. Straight treatments were tested in 2008 (Table 4) and tank mixtures were tested in 2009 (Table 5). The main weeds present in both years were annual meadow grass, American willowherb and hairy bittercress (*Cardamine hirsutum*)

- Reglone was only partially effective at controlling runners and weed growth.
- Shark was much less effective than Harvest at controlling runners and left some weeds uncontrolled, particularly annual meadow grass.
- Harvest was an effective treatment for runner control when used at the 5 L/ha rate. The addition of Shark improved weed and runner control compared with harvest alone but the difference was slight.
- Because no runner translocation damage resulted from any of the treatments, it is not possible to say if the addition of Shark could act as a safener for Harvest when used in the autumn on non-cut runners. However because of the relative lack of activity of Shark on strawberry runners this effect is unlikely
- For control of cleavers (*Galium aparine*) and small nettles (*Urtica urens*), Shark does have some advantages over Harvest although these weeds were not present in the experiments reported here.

Table 4. Contact herbicide treatments applied to the alleyway between strawberry beds 2008 experiment

Product	***Active ingredient***	***Product rate***	***Approval status (strawberries)***
Shark	carfentrazone-ethyl (60 g/L)	0.8 or 1.6 L/ha	Not approved
Harvest	glufosinate-ammonium (150 g/L)	5.0 L/ha	Label
Reglone	diquat	2.0 L/ha	Label

Table 5. Contact herbicide treatments applied to the alleyway between strawberry beds 2009 experiment

Product	***Active ingredient***	***Product rate***	***Approval status (strawberries)***
Shark	carfentrazone-ethyl (60 g/L)	1.6 L/ha	Not approved
Havest	glufosinate-ammonium (150 g/L)	5.0 L/ha	Label
Harvest + Shark	glufosinate-ammonium (150 g/L) + carfentrazone-ethyl (60 g/L)	3.0 L/ha 1.6 L/ha	Label Not approved
Harvest + Shark	glufosinate-ammonium (150 g/L + carfentrazone-ethyl 60 g/L)	5.0 L/ha 1.6 L/ha	Label Not approved

Shark application over crop foliage

In an evaluation of dormant season overall application, Shark was applied at two rates (0.33 and 0.8 L/ha) and three application timings (1 December 2009, 28 January and 8 April 2010) to strawberries grown on plastic covered raised beds or traditional matted rows.

- The December and January applications did not result in any crop injury or loss of crowns.
- The April applications scorched the leaf that was present at the time of spraying but the plants re-grew strongly. There was no loss of crowns, flowers or reduction in berry numbers at the time of first pick although the overall crop canopy was slightly thinner at one site.
- American willowherb was controlled on the Shark treated plots and dandelions present at one site were scorched and effectively controlled. The lower rate was as effective as the higher rate.

Financial benefits

Some of the most effective treatments tested, Chikara (on soil pathways) 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. Dual Gold now has a SOLA for use in strawberries and could contribute to general weed control. For example studies in Project HNS 139 showed that willowherb was effectively controlled and groundsel partially controlled.

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 saving, by eliminating the need for hand weeding (£2,100/ha or 300 hr/ha @ £7 per hr including overheads) and allowing for spray application costs (£100/ha), could amount to £2000/ha.

Action points for growers

- Now available, Dual Gold appears to be safe for use over strawberry beds and, subject to conditions on the SOLA (1389/10) 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 short term

residual control of groundsel. A low level of residue was detected in the fruit when tested at the higher rate pre-harvest – this use is not currently approved.

- Currently approved herbicides Dow Shield and Devrinol 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 currently approved on strawberries but similar formulations of phenmedipham are approved.
- Chikara was the most effective total herbicide for weed control between strawberry beds (Figs 1 and 2). 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. No damage was seen on the mother plants in early spring even though the runners were not cut when sprayed in the autumn.
- Shark has good potential for use as an overall dormant season clean-up treatment in both bed and matted row strawberries provided a SOLA can be obtained for this use.

Figure 1. Untreated control

Figure 2. Chikara-treated alleyway.

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 (*Senecio vulgaris*), redshank (*Polygonum persicaria*), knotgrass (*Polygonum aviculare*) and American willowherb (*Epilobium ciliatum*). 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 and its extension SF 91a aimed to 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 result 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 fumigants 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 and its extension aim to 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 evaluates Shark for runner and weed control in strawberry bed alleyways compared to industry standards. An extension to the project was granted to enable a further study to be

made of the effect of Shark when applied overall to strawberries for dormant season contact weed control (SF 91a, also reported here).

Materials and methods

Five experiments were done in 2009/10:

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.
5. Evaluation of Shark (carfentrazone-ethyl) applied over the crop foliage as a contact herbicide to selectively remove broad-leaved weeds during the dormant season.

1. Alleyway residual herbicides

Site details

Soil type

Silty loam. The soil nutrient indices were P (4), K (3), Mg (3), pH 7.7, organic matter 3.7%.

Previous cropping

Plastic-mulched beds were made up in 2005 and cropped with strawberry cv. Christine 2005 – 2008. The strawberry crop was sprayed off with Roundup (glyphosate 360 g/L) 5 L/ha in autumn 2008. The beds were left *in situ* for replanting in 2009.

Crop details

Cold stored 18+mm A++ light waiting bed runners of strawberry cv. Sonata were planted on 29 May 2009. All plants were supplied by Kraege, Germany. The plant spacing was 40 cm within row with two rows 30 cm apart on the bed. Crop husbandry

Prior to application of the experimental treatments the alleyways and beds were sprayed with Roundup (glyphosate 360 g/L) at 5 L/ha on 1 April 2009. Following the first weed control assessment, all plots were sprayed off on 18 June 2009 using Reglone (diquat 200 g/L) at 2 L/ha to remove all weed present.

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 6 for details)

The crop was not tunnelled.

Treatments

Treatments (Table 6) were applied on 7 April 2009 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 0.8m boom and F03-110 spray nozzles. Weather conditions at the time of treatment are detailed in appendix 7.

Experimental design

The experiment was laid out in a randomised complete block design with 12 treatments (Table 6) replicated four times (see Appendix 1 for layout). Plots dimensions were 1.6 m wide and 2.5 m long. Treatments were applied to the 0.8m wide un-cropped alleyway between plastic-mulched strawberry beds.

Assessments

Weed control was assessed on 5 June 2009 and 22 July 2009. Two 36 x 45 cm quadrats were placed centrally within the plot and used to assess percentage weed cover.

Plants were inspected on 5 June 2009 for signs of phytotoxicity arising from the herbicides applied to the adjacent pathway.

Table 6. 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	flazasulfuron (25% w/w)	0.15 kg/ha	Not approved
7.	Diuron 80WP	diuron (80% w/w)	1.25 kg/ha	Not approved
8.	Ronstar Liquid	oxadiazon (250 g/L)	4.0 L/ha	Not approved
9.	Sencorex WG	metribuzin (70% w/w)	0.7 kg/ha	Not approved
10.	Skirmish	terbuthylazine (420 g/L) + isoxaben (75 g/L)	1.0 L/ha	Not approved
11.	Springbok	dimethenamid-p (200 g/L) + metazachlor (200 g/L)	2.5 L/ha	Not approved
12.	Sumimax	flumioxazine (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 7) were applied on 4 June 2009 over the top of the strawberry beds. The runners had been planted six days earlier and at the time of spraying were in leaf but pre-flowering (Fig. 3). 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 7.

Figure 3. Growth stage at treatment, experiment 2.

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

No.	***Product***	***Active ingredient***	***Product rate***	***Approval status (strawberries)***
1.	Untreated			
2.	Dual Gold	s-metolachlor (960 g/L)	1.4 L/ha	Not approved
3.	Springbok	dimethenamid-p (200 g/L) + metazachlor (200 g/L)	2.5 L/ha	Not approved
4.	Goltix Flowable	metamitron (700 g/L)	5.0 L/ha	Not approved pre-harvest
5.	HDC H5	confidential (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 22 July 2009 by counting the number of weeds in the planting holes. Plants were inspected on 5 June and 1 July 2009 for signs of phytotoxicity arising from the herbicides. An assessment of plant vigour was made using a scoring system of 0 to 9 (Table 8).

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

Score	% damage or loss of vigour
0	No damage (as untreated controls)
1	0 –10% damage or loss of vigour
2	11 – 20% damage
3	21 – 30% damage
4	31 – 40% damage
5	41 – 50% damage
6	51 – 60% damage
7	61 – 70% damage
8	71 – 80% damage
9	81% – Complete kill

Fruit samples were picked from the s-metolachlor and metamitron treated plots for residue analysis by QTS Analytical, East Malling, Kent, on 16 July 2009 at the start of commercial picking.

An estimate of fruit yield was made on 22 July by taking a once-over harvest on four plants previously unpicked from the centre of the plot weighing all fruit, ripe and under-ripe.

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 17 June 2009 over the top of the strawberry beds. The runners had been planted 19 days earlier and at the time of spraying were in leaf but pre-flowering (Fig. 4). 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 7.

Figure 4. Plants on 12 June just prior to treatment, experiment 3.

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

No.	***Product***	***Active ingredient***	***Product rate***	***Approval status (strawberries)***
1.	Untreated			
2.	Alpha phenmedipham 320	phenmedipham (320 g/L)	1.25 L/ha	Label
3.	Dow Shield	clopyralid (200 g/L)	0.5 L/ha	Label but not for maidens
4.	Goltix Flowable	metamitron (700 g/L)	3.0 L/ha	Not approved pre-harvest
5.	Alpha phenmedipham 320 + Goltix Flowable	phenmedipham (320 g/L + metamitron 700 g/L)	1.25 L/ha + 3.0 L/ha	As above

Experimental design

The experiment was laid out in a randomised complete block design with five treatments (Table 9) replicated four times (see Appendix 3 for layout). Plot 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 1m wide spray swath.

Assessments

Weed control was assessed on 22 July 2009 by counting the number of weeds in the planting holes. Plants were inspected on 1 July and 15 July 2009 for signs of phytotoxicity arising from the herbicides. An assessment of plant vigour was made using a scoring system of 0 to 9 (Table 8).

Fruit samples were picked from the metamitron treated plots for residue analysis by QTS Analytical, East Malling, Kent, on 16 July 2009 at the start of commercial picking.

An estimate of fruit yield was made on 22 July by taking a once-over harvest on four plants previously unpicked from the centre of the plot weighing all fruit, ripe and under-ripe.

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

Site details

Soil type

Silty loam. The soil nutrient indices were P (2), K (2), Mg (2), pH 7.9, organic matter 3.2%.

Previous cropping

Winter wheat 2007. Plastic-mulched beds were made up in 2008.

Crop details

Cold stored 15+mm runners of strawberry cv. Sonata were planted on May 2008. All plants were supplied by Kraege, Germany. The plant spacing was 15 cm within row with two rows 30 cm apart on the bed. The crop developed normally and was picked as a 60 day crop in 2008 and as a maincrop in 2009.

Crop husbandry

After picking was completed the alleyways were sprayed with Harvest (glufosinate ammonium 150 g/L) at 5 L/ha on 21 July 2009. Further runners were produced after this application and these were subjected to the experimental treatments. The crowns were thinned by hand to four crowns per plant on 8 August 2009.

Fertiliser application followed normal industry practice (3 kg / ha N, 11 kg/ha K_2O per week) applied by fertigation weekly during September for 4 weeks.

Normal crop husbandry pesticide applications were made to the crop, mainly for disease control (see Appendix 6 for details)

The crop had been tunnelled, but the tunnels were removed after harvest.

Treatments

Treatments (Table 10) were applied on 29 September 2009 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 0.8 m boom and F03-110 spray nozzles. Weather conditions at the time of treatment are detailed in Appendix 7.

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 control			
2.	Shark	carfentrazone-ethyl (60 g/L)	1.6 L/ha	Not approved
3.	Harvest	glufosinate-ammonium (150 g/L)	5.0 L/ha	Label
4.	Harvest + Shark	glufosinate-ammonium (150 g/L) + carfentrazone-ethyl (60 g/L)	3.0 L/ha 0.8 L/ha	Label Not approved
5.	Harvest + Shark	glufosinate-ammonium (150 g/L) + carfentrazone-ethyl (60 g/L)	5.0 L/ha 0.8 L/ha	Label Not approved

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). Plot dimensions were 1.6 m wide and 2.5 m long. Treatments were applied as 0.8 m bands to the alleyway adjacent to the shoulder of plastic-mulched strawberry beds.

Assessments

Pre-treatment runner and weed levels were assessed on 29 September 2009 before any treatment effects would have been apparent. Post-treatment runner and weed assessments of percentage cover were made on 23 February 2010.

Plants were inspected on 27 October 2009 and 14 April 2010 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.

5. Evaluation of Shark (carfentrazone-ethyl) applied over the crop foliage as a contact herbicide

Site details

1) Manor Farm Hints, Tamworth
2) Essington Fruit Farm, Wolverhampton

Soil type

1) Sandy Clay Loam. The soil nutrient indices were P (2), K (1), Mg (2), pH 6.0
2) Sandy Clay Loam. The soil nutrient indices were P (3), K (3), Mg (4), pH 6.7

Crop details

1) Cold stored waiting bed plants of strawberry cv. Sonata were planted April 2008 by hand into plastic - mulched raised beds. The plant spacing was 30 cm within row with two rows 32.5 cm apart on the bed. The crop developed normally and was picked as a 60 day crop in 2008 and as a maincrop in 2009 and 2010.

2) Cold stored 12-15 mm runners of strawberry cv. Symphony were planted in April 2007 by machine into bare soil. The plant spacing was 45 cm within row and 1m between rows. The crop was picked as a late maincrop in 2008, 2009 and 2010.

Crop husbandry

1) After picking was completed an overall spray of Ramrod (propachlor 480 g/L) was applied in mid August 2009. The alleyways were further sprayed with Retro (diquat 200 g/L) at 2 L/ha in early September 2009. An overall application of Stomp 400SC (pendimethalin 400 g/L) + Flexidor 125 (isoxaben 125 g/L) + Devrinol (napropamide 450 g/L) at 7 L/ha was made on 6 February 2010. An alleyway application of Harvest (glufosinate-ammonium 150 g/L) at 3 L/ha was made in early May 2010. 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 but including a drench of Equity (480 g/L) at 2L/1000L applied for vine weevil control. The crop was tunnelled for the 2008 60 day crop and tunnelled and fleeced for the 2009 main crop. The crop was tunnelled on 13 May for the 2010 crop.

2) After picking was completed an overall spray of Ramrod (propachlor 480 g/L) was applied to beds and alleyways on 5 September 2009. The alleyways were further sprayed with Harvest (glufosinate ammonium 150 g/L) at 5 L/ha + Flexidor 125 (isoxaben 125 g/L) at 1 L/ha + Devrinol (napropamide 450 g/L) at 3.5 L/ha on 8 October 2009. No autumn fertiliser applications were made but in the early spring followed normal industry practice (typically 40 kg / ha N, 20 kg/ha P_2O_5, 80 kg/ha K_2O) applied as a broad acre dressing. Normal crop husbandry pesticide applications were made to the crop, mainly for disease control. In autumn 2009 Aliette (fosetyl-aluminium 80% w/w) at 3.75 kg/ha was applied for root disease control and Equity (480 g/L) 1 L/ha was applied for general pest control. In the spring (2010) Aliette at 3.75 kg/ha was applied for root disease control and Equity (480 g/L) at 1.5 L/ha was applied for blossom weevil control pre-blossom. Fungicides were applied for disease control, alternating Teldor (fenhexamid 50% w/w) at 1.5 kg/ha + Amistar (azoxystrobin 250 g/L) at 1 L/ha with Signum (boscalid 26.7% w/w +

pyraclostrobin 6.7% w/w) at 1.8 kg/ha + Systhane 20EW (myclobutanil 200 g/L) at 0.33 L/ha. The crop was not tunnelled.

Treatments

Treatments (Table 11) were applied on 1 December 2009, 28 January or 8 April 2010 to strawberry beds (1) or rows (2) 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 1.5 m (1) or 1.0 m (2) boom and F03-110 spray nozzles. Weather conditions at the time of treatment are detailed in Appendix 7.

Table 11. Applications of Shark (carfentrazone-ethyl 60 g/L) made directly over strawberry beds in Experiment 5

Treatment No.	***Product rate***	***Timing***
1	Untreated	
2	0.33 L/ha	1 December 2009
3	0.8 L/ha	1 December 2009
4	0.33 L/ha	28 January 2010
5	0.8 L/ha	28 January 2010
6	0.33 L/ha	8 April 2010
7	0.8 L/ha	8 April 2010

Experimental design

The experiment was laid out in a randomised complete block design with seven treatments (Table 11) replicated four times (see Appendix 5 for layout). Plot dimensions were (1) 1.5 m wide and 3.0 m long or (2) 1.0 m wide and 4.0 m long.

Assessments

Pre-treatment runner and weed levels were assessed on (1) 6 November 2009 or (2) 9 November 2009 before treatment, by counting the total number of weeds and the number of crowns and runners in the central 1.5 m x 1 m of the plot.

Post-treatment phytotoxicity assessments were made on 14 December 2009, 12 February 2010 and 10 April 2010 using a scoring system (Table 8). Post treatment assessments of weeds and strawberry crown and runner numbers were made on 10 April 2010 by counting the total number of weeds and the number of crowns and runners in the central 1.5 m x 1 m of the plot.

Plots were inspected and photographed during flowering on 22 May 2010 (site1) or 22 May 2010 (site 2) and the total number of fruit set per plant (site 1) or per m of row (site 2) was recorded on 12 June 2010 by count.

Fruit samples were picked from the April treated plots for residue analysis by QTS Analytical, East Malling, Kent, on 12 June (site 1) and 23 June 2010 (site 2) at the start of commercial picking.

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 subsequently, annual meadow grass (*Poa annua*) (Table 12), together with a more scattered distribution of sow thistle (*Sonchus oleraceus*), willowherb (*Epilobium ciliatum*), black nightshade (*Solanum nigrum*) and redshank (*Polygonum persicaria*) (data not presented). The best control was achieved initially by Chikara, Springbok, Ally SX, Ronstar Liquid, Sencorex WG and Sumimax (Table 12). Subsequently the longest lasting control was achieved by Chikara. Although numerically not quite so effective, Ally SX and Sencorex WG also performed well at the later assessment indicating reasonable persistence for groundsel and annual meadow grass control. Chikara

and Sencorex had also performed relatively well in 2008. Springbok and Ronstar Liquid performed well initially eight weeks after treatment but failed to maintain control of groundsel and annual meadow grass at the 22 July assessment, 15 weeks after treatment. Artist and Sumimax gave significant control of groundsel and annual meadow grass at both assessment dates in 2009 but were less effective than Chikara, Ally SX and Sencorex WG.

In both 2008 and 2009 weed control from Stomp 400SC + Flexidor 125, Calaris, and Skirmish were disappointing, mainly due to poor control of groundsel. Ally SX and Skirmish failed to control American willowherb, particularly in 2008 when it was more prevalent. Diuron was disappointing for control of groundsel and annual meadow grass but its main strength is for willowherb control. 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 in both years.

Table 12. Alleyway mean percentage weed cover 5 June and 22 July 2009

Treatment	***% Groundsel***		***% Annual Meadow grass***
	5 June	22 July	22 July
1 Untreated control	26.9	9.9	9.9
2 Stomp 400SC + Flexidor 125	24.1	5.5	7.5
3 Ally SX	2.5	1.9	0.4
4 Artist	10.6	2.2	0.4
5 Calaris	13.4	4.5	1.2
6 Chikara	0.0	0.0	0.0
7 Diuron 80 WG	22.5	3.7	2.6
8 Ronstar liquid	4.2	8.0	5.0
9 Sencorex WG	5.0	1.9	0.6
10 Skirmish	10.0	2.6	0.6
11 Springbok	0.8	7.1	3.1
12 Sumimax	8.0	5.4	0.7
F. pr	0.027	0.001	0.046
d.f.	33	33	33
l.s.d	17.33	4.20	6.30

Figure 5. Untreated control

Figure 6. Chikara-treated alleyway.

Figure 7. Sencorex WG-treated alleyway

Figure 8. Ally SX-treated alleyway showing willowherb

Figure 9. Stomp 400SC + Flexidor 125-treated alleyway showing groundsel

Figure 10. Ronstar Liquid-treated alleyway showing a few groundsel

Phytotoxicity

No phytotoxicity was noted at any of the assessment dates

2. Over-bed residual herbicides

Weed control

Relatively few weeds developed in the planting holes, consequently there were no significant differences between treatments. In the previous year, where weed development along the bed edge was recorded, the most effective treatment was Goltix Flowable.

Crop vigour and yield

There was variability in the plant growth regardless of treatment. Consequently the untreated control scored more than zero for phytotoxicity because of poor growth in some of the plants. The Dual Gold and Goltix Flowable treated plants were largely unaffected by treatments (Figs 11, 12) although a few of the Goltix Flowable treated plants had yellowed leaf margins (Fig 11). Plants treated with HDC H5 were slightly reduced in size (Fig 17) compared with the control, with a consequent increase in phytotoxicity score (Table 13). Similar effects were experienced in 2008. Springbok was not tested in 2008, but in this experiment caused a significant reduction in plant growth and some leaf crinkling (Figs 14, 15).

Yields were relatively low, as might be expected from a “once over” harvest that included over-mature fruit and under-ripe fruit. There was some variability as a result of the variable plant quality and differences were not significant. However there was an apparent trend for yield to be reduced with the treatments causing most phytotoxicity: Springbok and HDC H5.

Figure 11. Goltix treated showing slight leaf yellowing

Figure 12. Untreated control

Figure 13. Dual Gold treated, showing no damage.

Figure 14. Springbok treated eight days after treatment, showing distortion.

Figure 15. Springbok treated 27 days after treatment. Some recovery but still stunted.

Figure 16. HDC H5 treated eight days after treatment, showing distortion.

Figure 17. HDC H5 treated 27 days after treatment. Some recovery but still stunted.

Table 13. Mean phytotoxicity score (0 – 9, 9 = most phytotoxicity), assessed on 1 July 2008 from the over-bed bed residual herbicide experiment (Experiment 2)

Treatment		**Mean score**
1.	Untreated	0.50
2.	Dual Gold	0.52
3.	Springbok	1.33
4.	Goltix Flowable	1.01
5.	HDC H5	1.27
	P (ANOVA)	0.018
	df	12
	l.s.d	0.574

Once-over harvest yield was recorded towards the end of commercial picking (Table 14).

Table 14, Once-over mean harvest fruit yield (g) assessed on 22 July 2009 from the over-bed bed residual herbicide experiment (Experiment 2)

Treatment		**Fruit / plant (g)**
1.	Untreated	95.1
2.	Dual Gold	93.2
3.	Springbok	77.2
4.	Goltix Flowable	102.1
5.	HDC H5	71.9
	P (ANOVA)	0.231
	df	12
	l.s.d	ns

Residue analysis

No residues were detected in fruit samples from the Dual Gold and Goltix Flowable treated plots. No other residue samples were taken

3. Over-bed contact herbicides

Weed control

Relatively few weeds developed in the planting holes, consequently there were no significant differences between treatments. In the previous year, where weed development along the bed edge was recorded, the most effective treatment was Goltix Flowable.

Crop vigour and yield

There was some variability in the plant growth regardless of treatment. Consequently the untreated control scored more than 0 for phytotoxicity because of poor growth in some of the plants (Table 15). The Alpha phenmedipham 320 and Goltix Flowable treated plants were largely unaffected, although a few of the Goltix Flowable treated plants had yellowed leaf margins (Fig 18). Plants treated with the Alpha phenmedipham 320 + Goltix Flowable tank mixture were significantly reduced in size and yellowed compared with the control (Fig 19), with a consequent increase in phytotoxicity score.

Yields were relatively low, as might be expected from a “once over” harvest that included over-mature fruit and under-ripe fruit. There was some variability as a result of the variable plant quality and differences were not significant (Table 16). However there was an apparent trend for yield to be reduced with the treatments causing most phytotoxicity; Alpha phenmedipham 320 + Goltix Flowable.

Table 15. Mean phytotoxicity score (0 – 9, 9 = most phytotoxicity), assessed on 15 July 2009 from the over-bed bed contact herbicide experiment (Experiment 3)

Treatment		**Mean Score**
1.	Untreated	0.46
2.	Alpha phenmedipham 320	0.47
3.	Dow Shield	0.28
4.	Goltix Flowable	0.70
5.	Alpha phenmedipham 320 + Goltix Flowable	1.51
	P (ANOVA)	0.023
	df	12
	l.s.d	0.727

Figure 18. Slight marginal leaf yellowing caused by treatment with Goltix

Figure 19. Moderate marginal leaf yellowing caused by treatment with Goltix + Alpha phenmedipham 320.

Table 16. Once-over mean harvest yield (g / plant) assessed on 22 July 2009 from the over-bed bed contact herbicide experiment (Experiment 3)

Treatment		**Weight/plant (g)**
1.	Untreated	76.9
2.	Alpha phenmedipham 320	89.7
3.	Dow Shield	86.6
4.	Goltix Flowable	80.3
5.	Alpha phenmedipham 320 + Goltix Flowable	79.8
	P (ANOVA)	0.918
	df	11
	ns	ns
	L.S.D.	ns

Residue analysis

No residues were detected in fruit samples from Goltix Flowable treated plots taken at the start of picking. No other residue samples were taken

4. Alleyway contact herbicides

Weed and runner control

The most effective treatment for weed and runner control was Harvest (Table 17, Fig. 21), particularly when used at the normal 5 L/ha rate. Ground cover by runners was significantly reduced by all the Harvest treatments. The addition of Shark slightly improved control of runners and weed, but where the rate of Harvest was reduced in the tank mixture, control was reduced even with the addition of Shark (Table 17). Shark was relatively ineffective where used alone for runner control, even at the higher (1.6 L/ha) rate (Fig. 22). Differences in the amount of weed and runner between the plots prior to treatment were small and not statistically significant. Using the pre-treatment data as a covariant had some effect (p = 0.82), but was insufficient to affect the conclusions

For the weed cover in February there was no significant treatment difference and the covariant had no effect. The exceptional weed cover in two plots had a large effect on the overall means and variablility.

Table 17. Percentage cover weed and runners, pre-treatment (29 November 2009) and post-treatment (23 February 2010). (Experiment 4)

		Pre - treatment		***Post - treatment***	
No.	***Product***	***% Weed***	***% Runners***	***% Weed***	***% Runners***
1.	Untreated control	5.00	11.25	17.50	15.00
2.	Shark	4.00	9.50	18.75	10.00
3.	Harvest	2.00	8.00	6.25	1.50
4.	Harvest + Shark	6.25	12.50	12.50	4.75
5.	Harvest + Shark	3.75	12.00	1.00	0.75
	P (ANOVA)	0.144	0.323	0.177	<.001
	df	12	12	12	12
	L.S.D.	ns	ns	ns	5.89

	
Figure 20. Untreated runners and weed in alleyway.	*Figure 21*. Harvest at the higher rate gave good control of runners and weed

	
Figure 22. Shark did not control runners or annual meadow grass	*Figure 23*. the addition of Shark to Harvest at the higher rate improved control slightly

The predominant weeds over the winter period were annual meadow grass, hairy bittercress and willowherb with small amounts of groundsel. From observation, Harvest controlled all species well. Shark controlled American willowherb but not annual meadow grass.

Phytotoxicity

No phytotoxicity was noted from any of the treatments when assessed at the onset of picking (9 June 2010). 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 11% in the control, it is possible that more damage could result from treatment of more extensive runner cover.

5. Evaluation of Shark (carfentrazone-ethyl) applied over the crop foliage as a contact herbicide

Weed control

Site 1 had low levels of American willowherb present over winter. Levels were too variable for statistical analysis, but it was observed that up to 7 cm diameter American willowherb present at the time of spraying both rates and all timings of application of Shark was scorched and controlled (Fig 33). Dandelion was also scorched and satisfactorily controlled at this site. At site 2, weed levels were again too low for statistical analysis but, where present, American willowherb was controlled by the Shark treatments. Dandelion was present in some plots prior to treatment and was eradicated by the April assessment.

Phytotoxicity and crown number assessments

The first two timings of Shark application were made when the plants were dormant on 1 December 2009 and 28 January 2010 and when observed on 14 December 2009 and 12 February 2010 there were no signs of foliar scorch on the strawberry plants. At the time of the 8 April 2010 application growth had started (Fig 34) and young foliage was sprayed together with overwintered leaf. Phytotoxicity scores recorded on 17-18 April 2010 (Table 18) at both sites showed a clear effect from the April application, with slightly less effect from the lower rate at site 1 but with little difference between rates at site 2. However the affected plants were observed to produce a new canopy of fresh leaf and produced similar fruit numbers when recorded at first pick (12-13 June) (Tables 20, 21). Plants at site 1, which received the higher rate treatment in April, were observed to have a slightly thinner canopy at picking (Fig 25); no other differences in canopy density were noted from any of the other treatments. Crown numbers were recorded at both sites in November and again in April after all treatments had been applied. At site 2 there was an increase in average crown number per m from 11.5 to 15.0 over the period. At site 1 there was a small decrease in crown numbers recorded from 22.8 to 21.2. There were no differences in crown numbers between treatments at both sites when recorded in April (Table 19). The pre - treatment crown number counts were used as a covariant. However the use of the covariant factor was only significant at site 2.

	
Figure 24. Untreated just prior to picking at site 1.	*Figure 25.* Shark 800 ml/ha applied in April. Good recovery but a slightly thinner canopy at site 1.

	
Figure 26. Untreated at flowering on May 20 at site 1.	*Figure 27.* Shark 800 ml/ha applied April at flowering on May 20 at site 1. Older leaf at base burnt off but strong re-growth.

Figure 28. Untreated at flowering on May 20 at site 1.

Figure 29. Shark 800 ml/ha applied April at flowering on May 20 at site 1. No reduction in flowering,

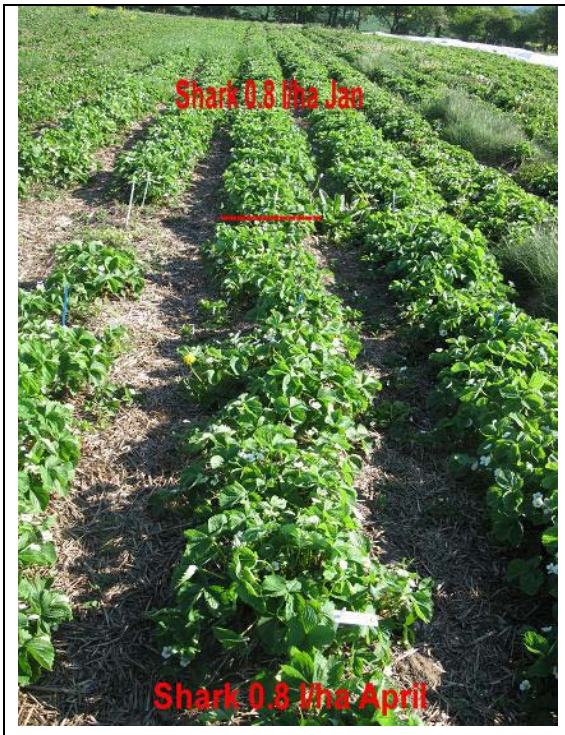


Figure 30. Site 2. Slightly thinner canopy from April applied Shark compared with January applied.

Figure 31. Site 2. Slightly thinner canopy from April applied Shark compared with untreated control.

Figure 32. April, higher rate Shark treated, nine days after treatment. December treated in background.

Figure 33. American willowherb controlled by Shark application, January (LHS) or April (RHS)

Figure 34. Stage of growth seven days prior to the April application of Shark.

Figure 35. Stage of growth (November) prior to first (December 1) treatment. Site 1

Figure 36. Untreated on 18 April at site 1.

Figure 37. December 1 application on 18 April at site 1. No damage

Figure 38. January 28 application on 18 April at site 1. No damage.

Table 18. Effect of Shark application timing and rate on phytotoxicity score (scale 0-9, 9 = most phytotoxic) recorded on 17-18 April 2010

Treatment no. *and rate*	**Timing**	**Rate (ml/ha)**	**Phytotoxicity score (0 - 9)**	
			Site 1	Site 2
1. Untreated	-	-	0.5	0.5
2. 0.33 L/ha	1/12/09	330	0	1.5
3. 0.8 L/ha	1/12/09	800	0	0.5
4. 0.33 L/ha	28/2/10	330	0	0
5. 0.8 L/ha	28/2/10	800	0	0
6. 0.33 L/ha	8/4/10	330	5	6.5
7. 0.8 L/ha	8/4/10	800	8	8.3
P (ANOVA)			<0.001	<0.001
df			18	18
L.S.D.			1.93	2.56

Table 19. Effect of Shark application timing and rate on total crown numbers per m recorded on 10 April 2010

Treatment no. *and rate*	**Timing**	**Rate (ml/ha)**	**Crowns per m row/bed**	
			Site 1	Site 2
1. Untreated	-	-	20.5	14.3
2. 0.33 L/ha	1/12/09	330	21.9	15.0
3. 0.8 L/ha	1/12/09	800	21.9	14.5
4. 0.33 L/ha	28/2/10	330	21.6	15.4
5. 0.8 L/ha	28/2/10	800	20.7	15.1

6. 0.33 L/ha	8/4/10	330	19.0	14.9
7. 0.8 L/ha	8/4/10	800	22.7	15.9
P (ANOVA) Treatment			0.654	0.910
P (ANOVA) Covariate			0.350	0.012
df			18	18
L.S.D.			ns	ns

Table 20. Effect of Shark application timing and rate on average berry numbers per plant recorded at the onset of picking (12 June 2010), site 1

Treatment no. *and rate*	**Timing**	**Rate (ml/ha)**	**Average berry number / plant**
1. Untreated	-	-	80.2
2. 0.33 L/ha	1/12/09	330	75.8
3. 0.8 L/ha	1/12/09	800	86.8
4. 0.33 L/ha	28/2/10	330	86.4
5. 0.8 L/ha	28/2/10	800	78.4
6. 0.33 L/ha	8/4/10	330	84.4
7. 0.8 L/ha	8/4/10	800	69.9
P (ANOVA)			0.693
df			18
L.S.D.			ns

Table 21. Effect of Shark application timing and rate on average berry numbers per m row recorded on 13 June 2010 just prior to the onset of picking, site 2

Treatment no. ***and rate***	**Timing**	**Rate (ml/ha)**	**Average berry number / m**
1. Untreated	-	-	226.5

2. 0.33 L/ha	1/12/09	330	190.3
3. 0.8 L/ha	1/12/09	800	142.9
4. 0.33 L/ha	28/2/10	330	186.5
5. 0.8 L/ha	28/2/10	800	232.8
6. 0.33 L/ha	8/4/10	330	147.3
7. 0.8 L/ha	8/4/10	800	203.5
P (ANOVA)			0.325
df			18
L.S.D.			ns

Residue analysis

No residues were detected in fruit samples from the April Shark treated plots at either rate taken at the start of picking from both sites. No other residue samples were taken

Effect on non-target organisms

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

Conclusions

1. Alleyway residual herbicides

Chikara and Sencorex appeared to provide the best overall weed control for the alleyways taking both years of experiments into account. All provided good control of annual meadow grass, groundsel, willowherb and sowthistle and had good persistence. 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. Artist contains the same active ingredient (metribuzin) as Sencorex but at a lower rate and already has a SOLA for use in bush fruit, though not in other soft fruit.

Alley SX performed well in the current experiment where groundsel and annual meadow grass was predominant, but was less effective in 2008 when more

willowherb was present. Ronstar Liquid and Springbok were initially very effective in the current experiments but did not have the persistence of Chikara.

Goal 2E also performed well in the 2008 experiments but it is not available in the UK and has been withdrawn from consideration for Annex 1 listing, so the future status of 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 was found was from the use of full rate Goltix Flowable in the 2008 experiment and the amounts were small, only 20% of the MRL. When the experiment was repeated in 2009 no residues were detected. 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, Dacthal W-75 and Ramrod. Two new residual herbicides Dual Gold and HDC H5 show potential for selective use in strawberries, although there was some loss of vigour from the use of HDC H5. HDC H5 is not currently available in the UK and it would not be possible to aquire a SOLA for its use on strawberries until it was approved for use on another crop in the UK. Dual Gold has recently become available in the UK as a herbicide for maize and there is a SOLA for its use on strawberries. In both years no residues of s-metolachlor were found in the fruit following pre-flowering applications of Dual Gold. Goltix Flowable also appears relatively safe and currently has a SOLA for use after harvest. It is particularly useful for groundsel control. A SOLA would be required to extend its use pre- harvest.

3. Over-bed contact herbicides

Phenmedipham products, Dow Shield and Goltix Flowable (lower rate) treatments did not give rise to any fruit residues or crop damage. Alpha phenmedipham 320 and Dow Shield are already approved for us in strawberries, although the label for Dow Shield does not cover use on maidens. The new treatment Defy proved to be too damaging to flowers and foliage and reduced yields in 2008.

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 were considered in the 2009 experiments. The addition of Shark to the 5 L/ha Harvest treatment gave slightly improved control of runners and weed compared to the standard Harvest treatment. There does not appear to be any scope for reducing the rate of Harvest when adding Shark however as the tank mixture with a 3 L/ha rate of Harvest was less effective. Shark would require a SOLA for use as an alleyway treatment in strawberries.

5. Evaluation of Shark (carfentrazone-ethyl) applied over the crop foliage as a contact herbicide

Shark shows promise for use as an overall selective dormant season treatment in strawberries. When applied in early December 2009 the plants were still green, having experienced a relatively mild autumn. In spite of that there was no discernable damage. When application was made at the end of January 2010 the plants were fully dormant following a spell of colder weather and again there was no damage. The final treatment was made when the plants were growing away in early April. The existing foliage was scorched but the plants re-grew strongly and there was no adverse effect on flowering, crown numbers or berry numbers at first pick. It would appear that there was little, if any, translocation into the crown and consequently there may be scope to treat plants that are starting to grow away in the spring, although it would be safer to treat dormant plants. American willowherb and dandelion were controlled by Shark, but groundsel was not affected. The control of overwintered willowherb and dandelion could be very useful in strawberries. Shark would require a SOLA for use as an overall dormant season treatment in strawberries.

Technology transfer

Results from the project were highlighted in the *HDC News Soft Fruit Review* November 2009.

An HDC News article is planned for October 2010.

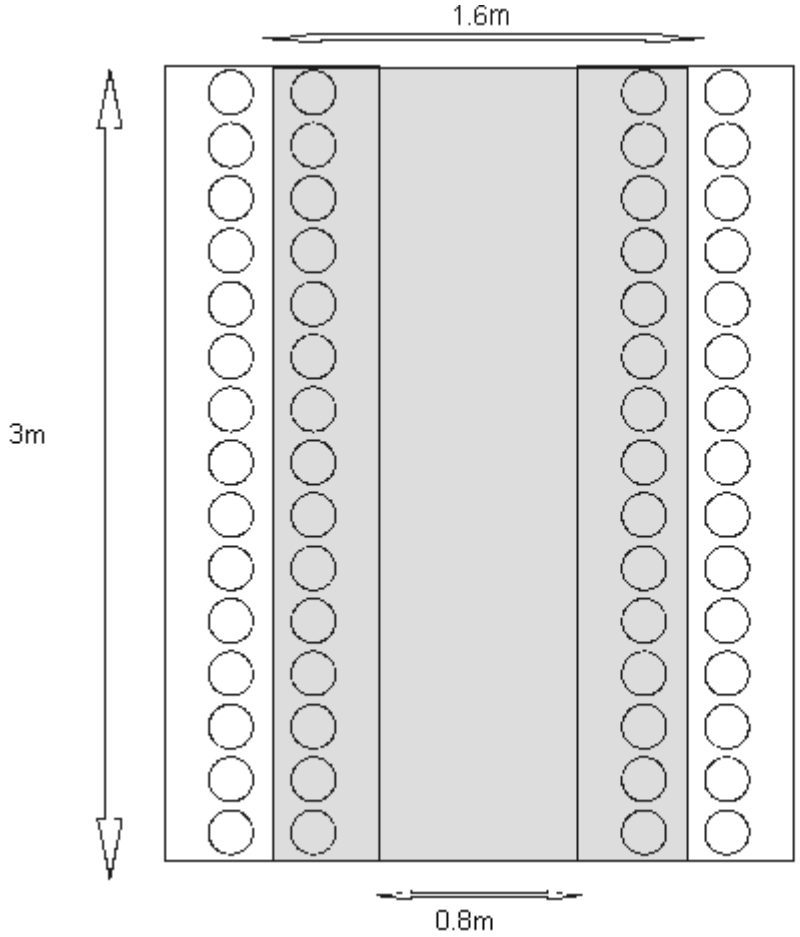
Appendices

Appendix 1. Experiment 1 layout

I	II	III	IV
12 6	24 9	36 9	48 12
11 8	23 4	35 6	47 1
10 12	22 2	34 12	46 3
9 1	21 6	33 11	45 11
8 11	20 11	32 2	44 10
7 10	19 5	31 3	43 9
6 4	18 10	30 8	42 8
5 3	17 3	29 1	41 6
4 9	16 12	28 5	40 4
3 7	15 1	27 4	39 2
2 5	14 8	26 7	38 7
1 2	13 7	25 10	37 5

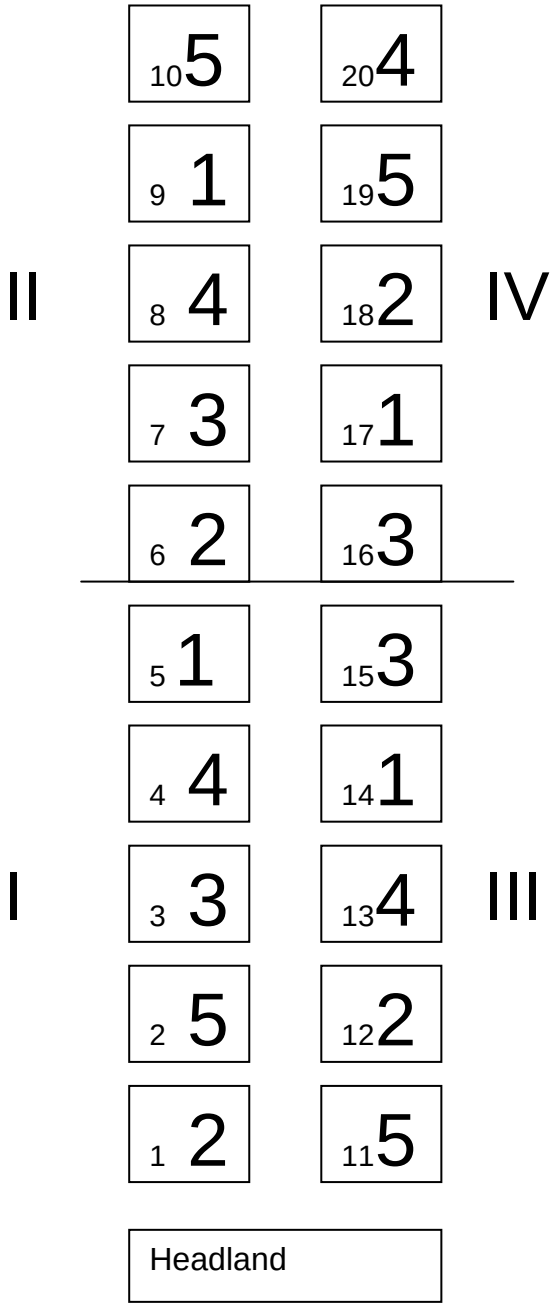
Treatment		*Active ingredient*	*Product rate*
1.	Untreated control		
2.	Stomp 400SC + Flexidor 125	pendimethalin + isoxaben	3.3 L/ha + 2.0 L/ha
3.	Ally SX	metsulfuron methyl	0.03 kg/ha
4.	Artist	flufenacet + metribuzin	2.5 kg/ha
5.	Calaris	terbuthylazine + mesotrione	1.5 L/ha
6.	Chikara (Mission)	flazasulfuron	0.15 kg/ha
7.	Diuron 80WG	diuron	1.25 kg/ha
8.	Ronstar Liquid	oxadiazon	4.0 L/ha
9.	Sencorex WG	metribuzin	0.7 kg/ha
10.	Skirmish	terbuthylazine + isoxaben	1.0 L/ha
11.	Springbok	metazachlor + dimethenamid -p	2.5 L/ha
12.	Sumimax	flumioxazine	0.1 L/ha

Sprayed area 0.8m x 3.0m



Appendix 2. Experiment 2 layout

Plot length 3.0m (including 0.5m guard between plots), Plot width 1.5

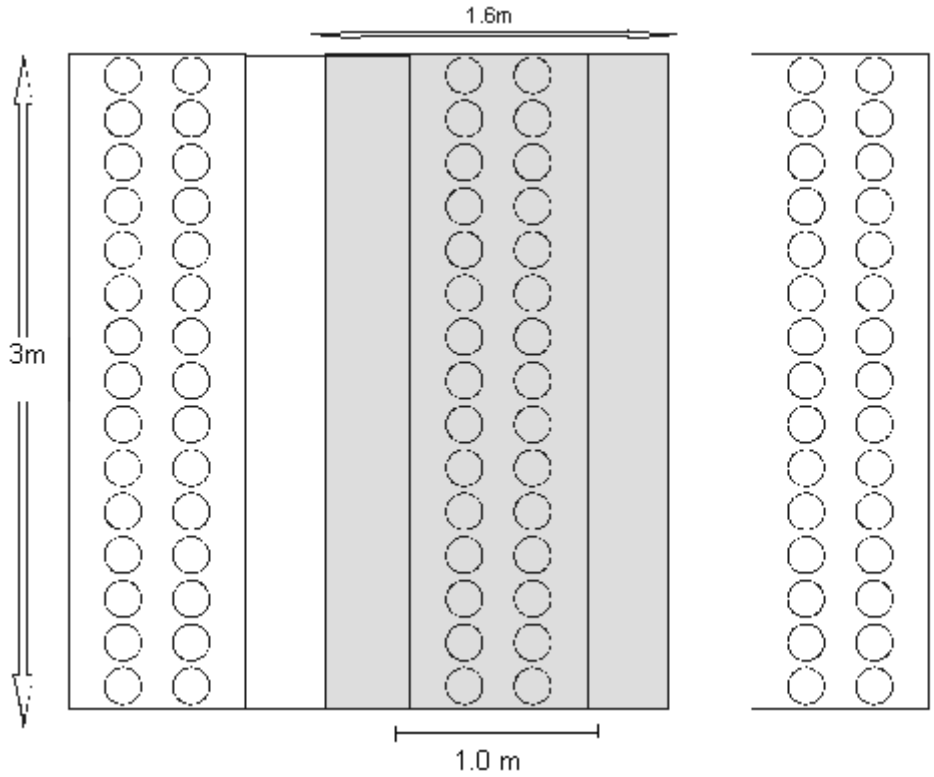


Treatment list

Treatment	*Product*	*Active ingredient*	*Product rate*
1.	Untreated control		
2.	Dual Gold	s-metolachlor	1.6 L/ha
3.	Springbok	metazachlor + dimethanamid-p	2.5 L/ha
4.	Goltix Flowable	metamitron	5.0 L/ha
5.	HDC H5 (A5089H)	confidential	3.0 L/ha

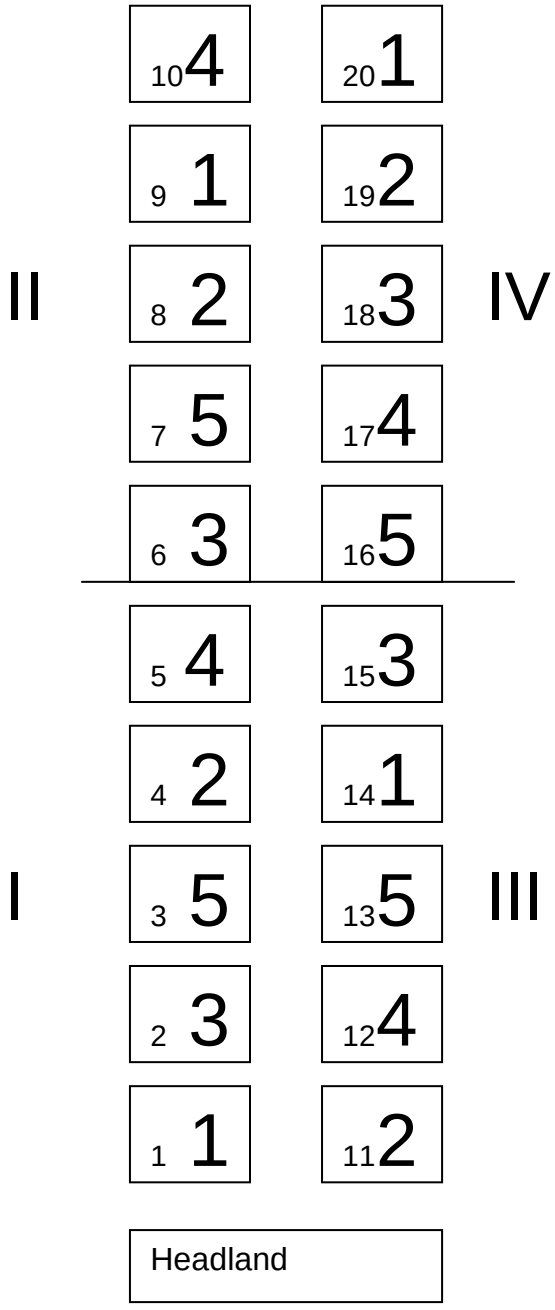
Plot layout

Sprayed area 1.0m x 3.0m



Appendix 3. Experiment 3 layout

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

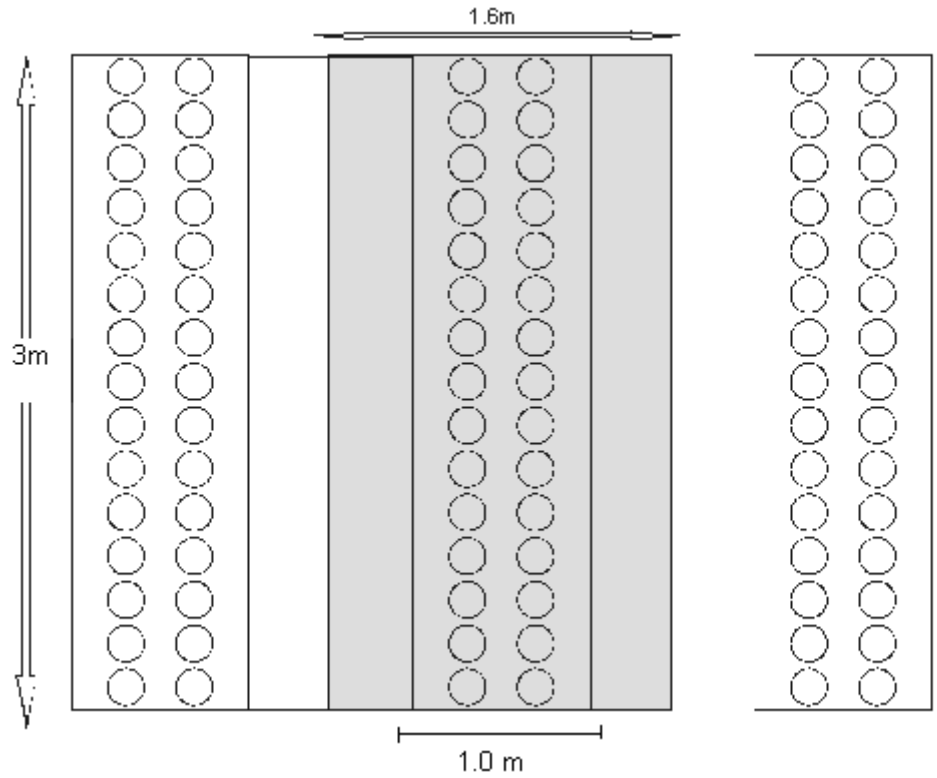


Treatment List

	Product	*Active ingredient*	*Product rate*
1.	Untreated control		
2.	Alpha phenmedipham 320 SC	phenmedipham	1.25 L/ha
3.	Dow Shield	clopyralid	0.5 L/ha
4.	Goltix	metamitron	3.0 L/ha
5.	Alpha phenmedipham 320 SC + Goltix	phenmedipham + metamitron	1.25 + 3.0 L/ha

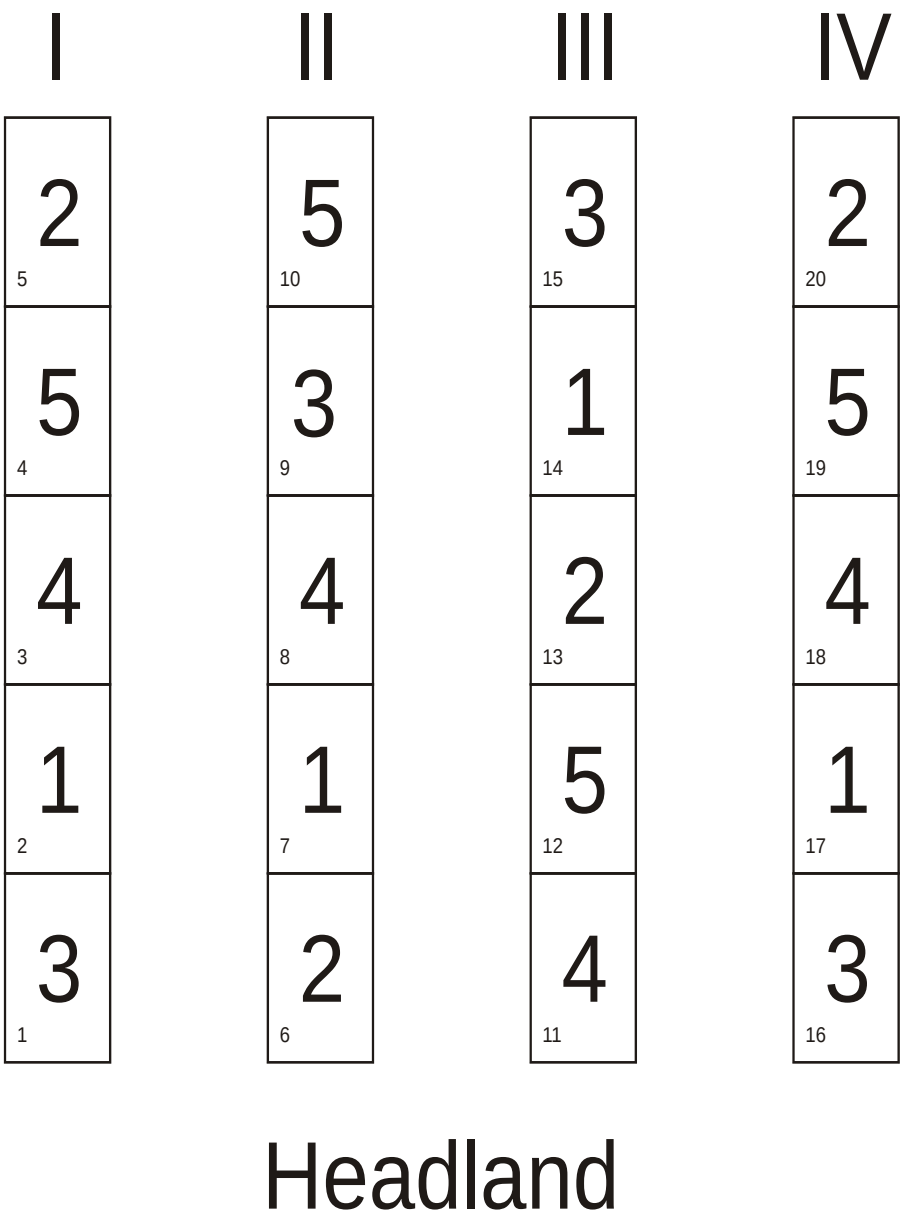
Plot Layout

Sprayed area 1.0m x 3.0m



Appendix 4. Experiment 4 layout

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

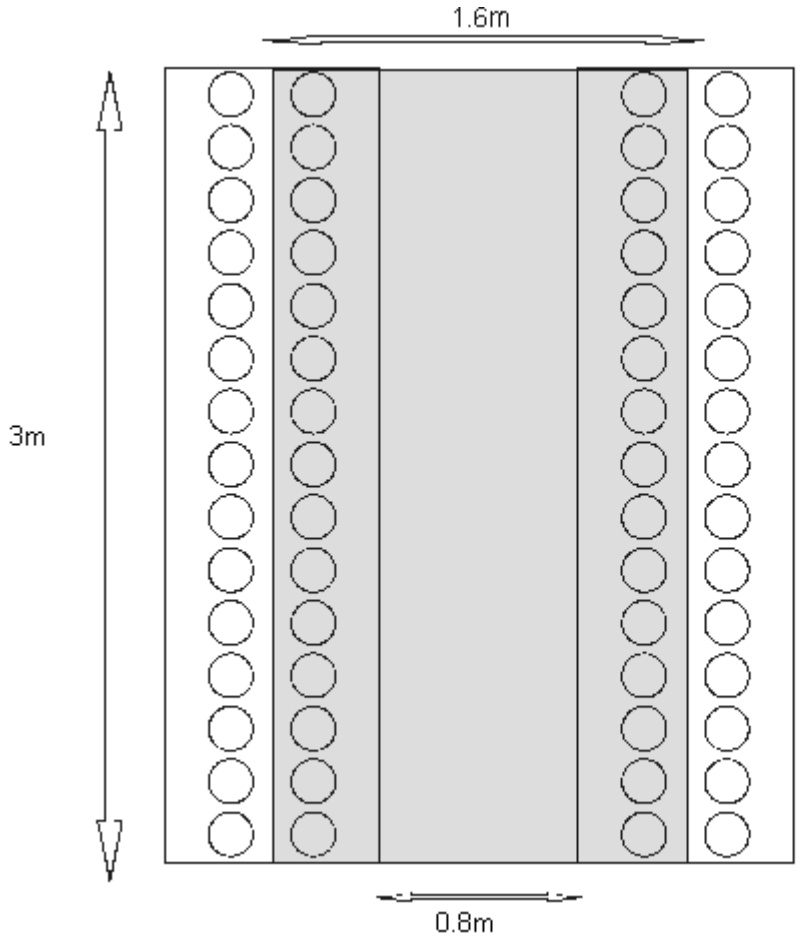


Treatment List

Treatment	*Product*	*Active ingredient*		*Product rate*
1.	Untreated control			
2.	Shark	carfentrazone-ethyl		1.6 L/ha
3.	Harvest	glufosinate-ammonium		5.0 L/ha
4.	Harvest + Shark	glufosinate-ammonium	+	3.0 L/ha
		carfentrazone-ethyl		0.8 L/ha
5.	Harvest + Shark	glufosinate-ammonium	+	5.0 L/ha
		carfentrazone-ethyl		0.8 L/ha

Plot layout

Plant density is half that shown below as 50% of plants will be removed.



Sprayed area 0.8m x 3.0m

Appendix 5. Experiment 5 layout (both sites)

I	II	III	IV
3 7	**7** 14	**4** 21	**3** 28
2 6	**4** 13	**3** 20	**2** 27
6 5	**5** 12	**1** 19	**6** 26
4 4	**2** 11	**6** 18	**7** 25
1 3	**3** 10	**5** 17	**4** 24
5 2	**6** 9	**7** 16	**1** 23
7 1	**1** 8	**2** 15	**5** 22

Treatment List

Treatment	Product	Active ingredient	Product rate	Timing
1	Untreated control			
2	Shark	carfentrazone-ethyl	0.33 L/ha	Mid Nov '09
3	Shark	carfentrazone-ethyl	0.8 L/ha	Mid Nov '09
4	Shark	carfentrazone-ethyl	0.33 L/ha	Mid Jan '10
5	Shark	carfentrazone-ethyl	0.8 L/ha	Mid Jan '10
6	Shark	carfentrazone-ethyl	0.33 L/ha	Early March '10
7	Shark	carfentrazone-ethyl	0.8 L/ha	Early March '10

Plot layout

Width: 0.25m path + 1.0m bed + 0.25m path = 1.5m.

Length: 3.0m inc 0.5m guard

Sprayed area 1.5m x 3.0m

Width: 0.3m path + 0.3m bed and path + 0.3m path = 0.9m.

Length: 4.0m inc 0.5m guard

Sprayed area 1.0m x 4.0m includes overlap on path

Path Runner Zone	Double Row Plastic Bed Crop	Path Runner Zone
	X X	
	X X	
	X X	
	X X	
	X X	
	X X	
	X X	
	X X	
	X X	
	X X	
	X X	
	X X	
	X X	
	X X	

Path Runner Zone	Single Row Soil crop	Path Runner Zone
	X	
	X	
	X	
	X	
	X	
	X	
	X	
	X	
	X	
	X	
	X	
	X	
	X	
	X	

Appendix 6. Other pesticide applications

Crop husbandry pesticide applications (experiments 1-3)

Date	Product	Active ingredients	Rate / ha
Mid June	Paraat	dimethomorph 50% w/w	2 kg
Early July	Scala	pyrimethanil 400 g/L	1 L
	Systhane 20EW	myclobutanil 200 g/L	0.3 L
	Urea	N 46%	2 kg
	Hortephyte	Phosphate 300 g/L P_2O_5	2 L
	TEC	Trace element	2 L
Mid July	Teldor	fenhexamid 50 % w/w	1 kg
	Systhane 20EW	myclobutanil 200 g/L	0.3 L
	Urea	N 46%	2 kg
	Hortiphyte	Phosphate 300 g/L P_2O_5	2 L
	TEC	Trace element	2 L

Crop husbandry pesticide applications (post harvest - experiment 4)

Date	Product	Active ingredients	Rate / ha
16 July	Dynamec	abamectin 18 g/L	250 ml
	Fortress	quinoxyfen 500 g/L	250 ml
27 August	Systhane 20EW	myclobutanil 200 g/L	0.3 L
	Equity	chlorpyrifos 480 g/L	1 L
	Hortiphyte	Phosphate 300 g/L P_2O_5	2 L
	TEC	Trace element	2 L

Appendix 7. Weather conditions at the time of spraying

Weather conditions at the time of spraying experiment 1.

Ground condition	Dry
General weather	Moderate, sun and cloud
Temperature	14^{o}C
Wind direction	S-W
Wind speed	6 mph
Relative humidity	50%
Weather in previous 24hr	Dry
Weather post application	Rain
Drift	Slight

Weather conditions at the time of spraying experiment 2.

Ground condition	Damp
General weather	Moderate, sun and cloud
Temperature	15.5^{o}C
Wind direction	W
Wind speed	3 mph
Relative humidity	55%
Weather in previous 24hr	Moderate
Weather post application	Moderate
Drift	Slight

Weather conditions at the time of spraying experiment 3.

Ground condition	Moist
General weather	Warm, sun and cloud
Temperature	18.6^{o}C
Wind direction	W
Wind speed	2-3 mph
Relative humidity	59%
Weather in previous 24hr	Dry, warm
Weather post application	Not noted
Drift	Slight

Weather conditions at the time of spraying experiment 4.

Ground condition	Dry
General weather	Warm, sun and cloud
Temperature	20^{o}C
Wind direction	NW
Wind speed	5 mph
Relative humidity	62.7%
Weather in previous 24hr	Dry, warm
Weather post application	Dry
Drift	Slight

Weather conditions at the time of spraying experiment 5 (site 1 Manor Fm, Hints) application 1.

Ground condition	Damp
General weather	Damp, cool
Temperature	3.4-3.6^{o}C
Wind direction	S
Wind speed	1.5-3.4 mph
Relative humidity	80.7-81.9%
Weather in previous 24hr	Dry, frosty
Weather post application	Showery
Drift	None

Weather conditions at the time of spraying experiment 5 (site 2 Essington) application 1.

Ground condition	Damp
General weather	Overcast, cool
Temperature	4.4-4.7^{o}C
Wind direction	NW
Wind speed	3.3-4.1 mph
Relative humidity	79.5-79.7%
Weather in previous 24hr	Dry, frosty
Weather post application	Showery, cool
Drift	Slight

Weather conditions at the time of spraying experiment 5 (site 1 Manor Fm) application 2.

Ground condition	Damp
General weather	Overcast, humid, cool
Temperature	5.9-7.2^{o}C
Wind direction	NE
Wind speed	2.6-2.7 mph
Relative humidity	77.9-85.4%
Weather in previous 24hr	Showery, cool
Weather post application	Showery, cool
Drift	Slight

Weather conditions at the time of spraying experiment 5 (site 2 Essington) application 2.

Ground condition	Damp
General weather	Overcast, cool
Temperature	6.6-7.0^{o}C
Wind direction	N
Wind speed	4.2-4.4 mph
Relative humidity	78.3-76.0%
Weather in previous 24hr	Showery, cool
Weather post application	Showery, cool
Drift	Slight

Weather conditions at the time of spraying experiment 5 (site 1 Manor Fm) application 3.

Ground condition	Moist
General weather	Warm, sun and cloud
Temperature	18.6^{o}C
Wind direction	W
Wind speed	2-3 mph
Relative humidity	59%
Weather in previous 24hr	Dry, warm
Weather post application	Not noted
Drift	Slight

Weather conditions at the time of spraying experiment 5 (site 2 Essington) application 3.

Ground condition	Dry
General weather	Warm, sun and cloud
Temperature	20^{o}C
Wind direction	NW
Wind speed	5 mph
Relative humidity	62.7%
Weather in previous 24hr	Dry, warm
Weather post application	Dry
Drift	Slight

Appendix 8. Temperature and rainfall data 10 days prior to and post treatment

Experiment 1 treated 7 April 2009

Date	Daily Temperature *		Rainfall (mm)
	min	max	
29 March			0
30 March			0
31 March			0
1 April			0
2 April			0
3 April			0.2
4 April			0
5 April			0
6 April			0
7 April			0
8 April			0.6
9 April			0.8
10 April			1.2
11 April			0.4
12 April			0.2
13 April			0
14 April			0
15 April			0
16 April			2.6
17 April			0
18 April			0

Note – Temperature was not recorded

Experiment 2 treated 4 June 2009

Date	Daily Temperature		Rainfall
	min	max	
26 May	10.5	13.0	6.6
27 May	7.5	17.5	0.6
28 May	14.0	22.0	0
29 May	11.5	22.0	0
30 May	8.0	20.5	0
31 May	10.5	19.5	0
1 June	12.0	21.0	0
2 June	8.5	21.0	0
3 June	11.5	14.5	0
4 June	3.5	14.0	0
5 June	8.5	14.0	0
6 June	9.0	15.5	0.3
7 June	8.0	14.0	7.5
8 June	9.0	15.0	0.3
9 June	10.0	15.0	0.1
10 June	10.0	17.5	14.5
11 June	10.5	17.5	3.8
12 June	5.0	20.0	4.8
13 June	12.0	22.0	0
14 June	11.5	21.5	0
15 June	11.0	22.0	0.1

Experiment 3 treated 17 June 2009

Date	Daily Temperature		Rainfall
	min	max	
8 June	9.0	15.0	0.3
9 June	10.0	15.0	0.1
10 June	10.0	17.5	14.5
11 June	10.5	17.5	3.8
12 June	5.0	20.0	4.8
13 June	12.0	22.0	0
14 June	11.5	21.5	0
15 June	11.0	22.0	0.1
16 June	10.5	21.0	0
17 June	10.5	20.5	0
18 June	9.5	18.0	0
19 June	9.5	19.0	0
20 June	10.0	18.0	0.5
21 June	10.0	20.5	0
22 June	11.0	21.0	0
23 June	12.0	22.5	0
24 June	8.5	22.0	0
25 June	12.0	24.5	0
26 June	14.0	22.5	13.0
27 June	15.0	20.5	1.3
28 June	15.0	24.5	9.2

Experiment 4 treated 29 September 2009

Date	Daily Temperature		Rainfall
	min	max	
19 September	10.0	22.0	0
20 September	13.0	19.5	0
21 September	8.0	18.5	0
22 September	11.5	22.0	0
23 September	10.5	18.5	0
24 September	8.0	19.0	0
25 September	7.5	19.0	0
26 September	9.0	18.5	0
27 September	4.5	21.0	0
28 September	9.5	19.0	0
29 September	12.0	21.5	0
30 September	15.0	20.5	0
1 October	11.5	16.5	0
2 October	6.0	15.0	0
3 October	13.0	18.0	0.2
4 October	8.0	16.5	0
5 October	3.5	14.5	0
6 October	11.0	20.0	3.4
7 October	10.0	13.0	4.0
8 October	3.0	15.0	0
9 October	3.5	14.0	2.0

Experiment 5 treated 1 December 2009 (Site 1 Hints)

Date	Daily Temperature		Rainfall (mm)
	min	max	
21 November	4.14	12.94	7.6
22 November	4.85	9.70	1.7
23 November	5.00	12.42	4.2
24 November	5.61	12.59	5.9
25 November	3.44	11.13	3.6
26 November	1.80	10.49	0.2
27 November	0.75	10.32	0.8
28 November	1.07	5.77	8.8
29 November	3.84	8.42	2.4
30 November	-2.12	6.31	0.0
1 December	-3.92	4.03	1.6
2 December	3.82	8.20	0.6
3 December	-0.17	6.70	0.7
4 December	-2.35	8.93	5.4
5 December	2.94	9.41	10.0
6 December	3.03	10.52	0.0
7 December	2.28	9.68	5.2
8 December	1.79	8.93	1.1
9 December	3.97	9.38	2.8
10 December	-0.89	8.81	0.1

Experiment 5 treated 1 December 2009 (Site 2 Essington)

Date	Daily Temperature		Rainfall
	min	max	
21 November	5.48	12.17	8.4
22 November	5.46	7.95	0.8
23 November	5.69	10.45	2.6
24 November	6.19	10.95	6.8
25 November	4.32	10.47	2.0
26 November	2.83	8.88	0.2
27 November	1.76	6.94	2.3
28 November	1.87	4.58	6.5
29 November	3.09	6.07	7.2
30 November	-0.78	4.90	0.0
1 December	-0.39	3.53	2.6
2 December	3.58	7.15	0.7
3 December	0.66	5.81	0.2
4 December	-0.62	5.75	3.8
5 December	3.66	9.24	9.6
6 December	3.85	10.42	1.4
7 December	2.86	8.41	2.2
8 December	2.24	8.93	0.3
9 December	5.23	8.44	2.5
10 December	0.38	8.16	0.1

Experiment 5 treated 28 January 2010 (Site 1 Hints)

Date	Daily Temperature *		Rainfall
	min	max	
18 January	-0.78	13.32	0.1
19 January	2.96	6.81	0.0
20 January	1.69	4.32	0.7
21 January	-1.58	9.20	1.2
22 January	3.85	8.94	14.0
23 January	-0.90	6.24	0.0
24 January	0.41	7.13	4.2
25 January	1.32	4.46	0.1
26 January	-3.46	10.34	0.0
27 January	-1.10	7.79	0.1
28 January	0.17	7.20	4.0
29 January	-4.14	9.11	0.1
30 January	-5.86	9.59	0.0
31 January	-3.67	5.66	0.2
1 February	-5.07	6.94	0.2
2 February	1.14	10.98	7.7
3 February	-2.27	5.62	1.5
4 February	-0.67	8.38	2.2
5 February	-0.92	14.68	0.0
6 February	-0.89	6.89	0.2
7 February	2.37	6.98	0.3

Experiment 5 treated 28 January 2010 (Site 2 Essington)

Date	Daily Temperature		Rainfall
	min	max	
19 January	0.48	8.89	0.0
20 January	1.54	5.74	0.7
21 January	1.73	3.06	1.8
22 January	0.23	4.26	7.5
23 January	3.84	7.45	0.0
24 January	-0.06	4.87	1.5
25 January	0.26	5.18	0.0
26 January	0.99	2.58	0.0
27 January	-1.32	4.16	0.6
28 January	-0.40	6.28	4.3
29 January	2.19	6.60	0.0
30 January	-2.43	4.28	0.0
31 January	-4.95	2.18	0.0
1 February	-4.25	1.46	0.3
2 February	-3.73	5.01	4.2
3 February	0.33	9.45	0.8
4 February	-0.78	3.46	1.5
5 February	-0.31	8.53	0.0
6 February	1.11	13.05	0.0
7 February	0.32	7.87	0.3

Experiment 5 treated 8 April 2010 (Site 1 Hints)

Date	Daily Temperature		Rainfall (mm)
	min	Max	
29 March	15.5	5.3	4.9
30 March	20.4	4.3	1.8
31 March	9.8	1.3	1.7
1 April	12.0	0.3	6.8
2 April	14.9	2.8	4.4
3 April	18.1	2.8	1.0
4 April	17.7	0.5	0.5
5 April	16.8	1.3	0.0
6 April	20.7	5.0	1.9
7 April	18.6	2.5	0.0
8 April	29.3	1.2	0.0
9 April	27.4	3.0	0.0
10 April	25.3	3.7	0.0
11 April	23.1	4.0	0.0
12 April	21.0	4.6	0.0
13 April	21.2	1.2	0.0
14 April	21.3	6.6	0.0
15 April	14.7	6.0	0.0
16 April	23.3	2.4	0.0
17 April	26.9	2.0	0.0
18 April	23.3	3.3	0.0

Experiment 5 treated 8 April 2010 (Site 2 Essington)*

Date	Rainfall (mm.)
29 March	2.5
30 March	1.4
31 March	1.5
1 April	3.5
2 April	3.8
3 April	0.0
4 April	1.2
5 April	0.0
6 April	1.2
7 April	0.0
8 April	0.0
9 April	0.0
10 April	0.0
11 April	0.0
12 April	0.0
13 April	0.0
14 April	0.0
15 April	0.0
16 April	0.0
17 April	0.0
18 April	0.0

*Note – Temperature was not recorded at this site