Project title:	Strawberry: Investigating rates and application timing of carfentrazone-ethyl (Shark)
Project number:	SF 151
Project leader:	Janet Allen, ADAS UK Ltd (Originally H. Roberts, ADAS UK Ltd)
Report:	Final report, December 2015
Previous report:	Annual report, December 2014
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Date project commenced:	1st February 2014
Date project completed	31st September 2015

DISCLAIMER

The results and conclusions in this report are based on an investigation conducted over a two-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

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

Emma Worrall

Horticultural Consultant

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Signature: Date: 20th October 2015

Report authorised by:

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GROWER SUMMARY

Headline

- Carfentrazone-ethyl (Shark) has potential as an overall treatment in established strawberries for selective post-emergence control of weeds in the planting holes.

Background and expected deliverables

Growers have very few options for the post-emergence control of broad leaved weeds found in soil and substrate grown strawberries. Diquat or glufosinate-ammonium based products can be used as spot treatments or shielded applications when applied to weeds growing in alleyways between crop beds but only clopyralid, phenmedipham and metamitron can be applied over a crop of strawberries. The range of weeds sensitive to clopyralid is limited and its use is more or less exclusively for the control of composite weeds e.g. groundsel, sowthistle (*Sonchus oleraceus*) and creeping thistle (*Cirsium arvense*). Use of clopyralid is also restricted to application between 1 March and 31 August (EAMU). The range of products containing phenmedipham with on label approval for use on strawberry is limited. Use of phenmedipham is restricted to pre-flowering and post-harvest and more or less exclusively post-planting during the establishment period of crops. Phenmedipham can provide control of quite a range of annual broad leaved weed species e.g. black-bindweed (*Fallopia convolvulus*), fat hen (*Chenopodium album*) and groundsel (*Senecio vulgaris*) but only at the small seedling stage. The use of metamitron is permitted by several EAMUs on the established strawberry crop, applied post-harvest, between September and November. Like phenmedipham, metamitron can provide post-emergence control of seedling weeds.

Currently, other than laborious and costly hand weeding, there are relatively few options for the control of annual broad-leaved weeds up to or beyond the two to four leaf stage, for soil and substrate grown strawberry crops. In addition, the herbicides with approval for use on strawberry either provide limited or no post-emergence control of cleavers (*Galium aparine*), hairy bitter cress (*Cardamine hirsuta*), American willowherbs (*Epilobium ciliatum*), black nightshade (*Solanum nigrum*), knotgrass (*Polygonum aviculare*), redshank (*Persicaria maculosa)* and speedwells (*Veronica*). It is estimated that to weed strawberries by hand could cost £1,200/ha. With several sessions of hand weeding required during the life of a strawberry crop, hand weeding is a very expensive method for growers to employ.

In projects SF 91 and 91a, Shark was evaluated initially as a directed spray for the control of strawberry runners (for which it proved ineffective), then as an over the crop dormant season spray. The results of these projects indicated that Shark caused very little lasting damage to the strawberry plants when applied in the dormant season, to the extent that it could be considered for use as an overall application for this crop.

The aim of this project was to refine rates of Shark and to further confirm crop safety and efficacy against problematic weeds (e.g. American willowherbs, cleavers, redshank and knotgrass) when applied both as a post-harvest and dormant season application.

This information could then be used to increase confidence in the use of Shark as a selective herbicide in strawberries and support an application for an EAMU to permit treatment over the crop both in the dormant season and also post-harvest, for the control of over wintering weeds around plants in soil and substrate grown crops.

Summary of the project and main conclusions

This project included three trials that tested different application timings of Shark; 1) dormant season, 2) post-harvest and 3) post-harvest followed by dormant season.

Trial one – Dormant season application of Shark

The dormant season trial was carried out on a protected (Spanish tunnel) June bearer strawberry crop (cv. Elegance), on a commercial farm in Cambridge. The crop was grown in coir filled bags, set on poly-mulch covered raised beds, and was entering its second (i.e. main season) cropping year. The crop contained a varied but uniform weed population typical of this method of crop production.

There were four treatments in this trial (**Table 1**). Each plot was three metres long and one row of coir filled bags wide, comprising approximately 30 plants. The treatments were applied on one occasion, 19 February 2014, using an air assisted knapsack Oxford Precision Sprayer (OPS) and lance.

Table 1. Treatment list for trial one (dormant season application)

Treatment no.	Treatment	Rate (L/ha)	Timing
1	Untreated	N/A	N/A
2	Hand-weeded	N/A	19 February 2014
3	Shark	0.33	19 February 2014
4	Shark	0.8	19 February 2014

The plots were assessed for any signs of damage or effects to strawberry plant growth some two, four and eight weeks after the treatments were applied and then again at harvest. Weed assessments were carried out prior to trial set up and also at two, four and eight weeks after treatments had been applied.

The fruit produced from the individual plots was harvested by farm staff over a three week period. Yield and number of berries of class one, class two and waste fruit was recorded.

Despite some initial scorching of overwintered green leaves (**Figure 1**), the use of Shark as an over the crop dormant season spray appeared to have no lasting phytotoxic effects on strawberry plants, yield or quality of fruit produced by treated plants (**Table 2**)**.** No statistically significant effects were seen as regards to weed control achieved from the use of either 0.33 or 0.8 L of Shark but this was due to the trial site's light weed population. Both rates of Shark displayed promising efficacy against American willowherbs, chickweed (*Stellaria media*) and both rates had some effect on groundsel. No residues of carfentrazone-ethyl were detected in fruit collected and submitted for analysis during the first harvest of the treated plants.

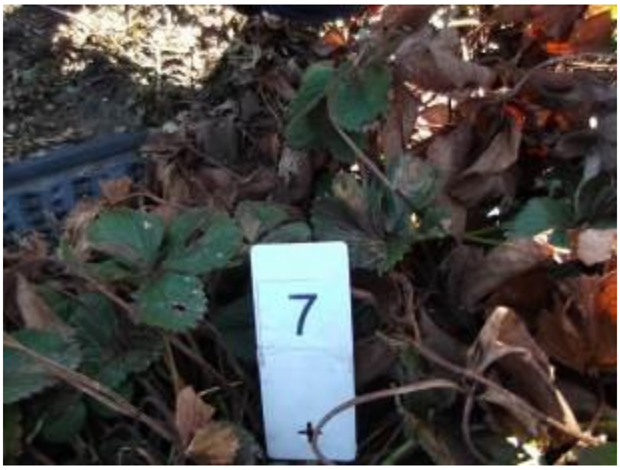

Figure 1. Scorching to plants treated with Shark (0.8 L/ha) was seen two weeks after treatment in the dormant season trial

Table 2. Results of dormant season applications on crop safety, weed control and marketable yield.

Treatment	Phytotoxicity 2 weeks after treatment	Phytotoxicity 8 weeks after treatment	% weed cover in alleyway 2 weeks after treatment	Average marketable yield g/plant
Untreated	9.0	9.0	20.0	700.31
Hand weeded	9.0	9.0	0.5	802.03
Shark 0.33 L/ha	8.0	9.0	14.5	774.96
Shark 0.8 L/ha	6.5	9.0	12.5	807.84
P value	<0.001	NS	0.017	NS
l.s.d. (d.f. 9)	0.884	NS	10.89	164.5

Phytotoxicity scored on a 0-9 scale where 0 is plant death and 9 is no effect

Trial two – Post-harvest application of Shark

The post-harvest trial was located on the same farm as the dormant season trial but this time the June bearer cv. Elsanta was used. The crop was planted in April 2014 as ex-cold stored A+ (13-19mm) runners that were sourced from the Netherlands. The crop was grown under a Spanish tunnel, which was clad from planting until harvest was completed (mid-July 2014) and then again from 7 April 2015 until September.

The post-harvest trial compared two rates of Shark (**Table 3**). Each plot was three metres long and one row of coir filled bags wide, comprising approximately 30 plants. The treatments were applied on one occasion, 22 July 2014, using an air assisted OPS knapsack sprayer and lance.

Table 3. Treatment list for trial two (post-harvest application)

Treatment no.	Treatment	Rate (L/ha)	Timing
1	Untreated	N/A	N/A
2	Hand-weeded	N/A	22 July 2014
3	Shark	0.33	22 July 2014
4	Shark	0.8	22 July 2014

For the post-harvest trial the strawberry plants were assessed for any damage two and four weeks after treatment application, the following March as growth commenced, at flowering and again prior to harvest in 2015. Weed populations were assessed at two and four weeks after treatment.

The fruit produced from the individual plots of both trials was harvested by farm staff over a three week period. The yield and number of berries of class one and waste fruit were recorded.

The post-harvest application of Shark also produced some initial scorching of the older leaves of treated strawberry plants (**Figure 2**). However, newly emerging leaves were unaffected and no signs of toxicity to crop foliage was observed when the next plant assessments were made in March 2015 (**Table 4**). At two weeks after application, both rates of Shark significantly reduced the number of weeds in planting holes, although no significant effect was seen with the number of weeds growing in the alleyways, between the treated crop rows. Assessments were carried out two and four weeks after Shark application to determine if Shark had any effect upon the incidence of powdery mildew. The number of live crowns per plant were also recorded. No significant effects were seen with powdery mildew incidence or number of live crowns per plant. There were no yield reductions in 2015 resulting from the previous season's application of Shark at 0.33 L/ha but where Shark was applied at 0.8 L/ha the plants produced a significantly lower yield of class one fruit.

Figure 2. Scorching to plants treated with Shark (0.8 L/ha) two weeks after treatment in the post-harvest trial

Table 4. Results of post-harvest season applications on crop safety, weed number and yield of class one strawberries.

Treatment	Phytotoxicity 2 weeks after treatment	Phytotoxicity as growth commences	No. weeds in planting holes 2 weeks after treatment	Class 1 yield g/plant
Untreated	9.0	9.0	4.0	391.97
Hand weeded	9.0	9.0	1.0	443.13
Shark 0.33 L/ha	7.5	8.9	0.8	435.49
Shark 0.8 L/ha	5.5	9.0	0.8	280.64
P value	<0.001	NS	0.032	0.005
l.s.d. (d.f. 9)	0.653	0.199	1.622	81.200

Phytotoxicity scored on a 0-9 scale where 0 is plant death and 9 in no effect

Trial three – Post-harvest and dormant season application of Shark

The final trial was located on two commercial farms; one near Cambridge where the treated cultivar was Elsanta, the other was set up at Wisbech where the cultivar used was Sonata. On both sites, the trial comprised two treated 20 m long rows of strawberries and two untreated 20 m long rows of strawberries. Shark was applied over the crop at 0.4 L/ha on two occasions to give a total dose of 0.8 L/ha (**Table 5**). Shark was applied to each site post-harvest, on 22 August 2014, and again in the dormant season, 6 March 2015.

Table 5. Treatment list for trial three (post-harvest and dormant season applications)

Treatment no.	Treatment	Rate (L/ha)	Timing
1	Untreated	N/A	N/A
2	Shark	0.4	22 July 2014 and 6 March 2015

No formal assessments were made for these trials, although samples of fruit were picked at harvest and submitted for Good Laboratory Practice (GLP) residue analysis to support an application for an Extension of Authorisation for Minor Use (EAMU) for the use of Shark on strawberry, as an over the crop treatment, post-harvest and in the dormant season.

No residues were detected in the berry samples submitted for these trials.

Financial benefits

At present, the use of chemical herbicides in the crop row and planting holes of strawberry crops from late winter to early spring and immediately post-harvest, is more or less impossible, whether the weeds are present as seedlings or established plants.

Considerable hand weeding of plants is therefore carried out in crops post-winter, prior to the onset of growth, and again as soon as the final fruits have been harvested. Growers have no options available for the post-emergence control of weeds such as American willowherbs, mallows, knotgrass, hairy bitter cress and small nettle; all of which often overwinter within strawberry crops. Similarly, soil grown crops often become contaminated with carfentrazone-ethyl susceptible weed species (redshank, pale persicaria, knotgrass and black nightshade) during harvest, which again can only be cleared by hand weeding.

It is estimated that the removal of weeds by hand could cost up to £1,200/ha per session. Typically, a strawberry plantation in a single growing season may require hand weeding on several occasions. Increasing the options available to commercial strawberry growers for post-emergence weed control could save growers in excess of £2,000/ha. The ability to use Shark on strawberry would therefore be very beneficial for growers.

Action points for growers

- For growers to benefit from this project, an EAMU would be required for carfentrazone-ethyl.
- A post-harvest application of Shark at the higher (0.8 L/ha) rate appears to carry the risk of yield reduction the following year.

SCIENCE SECTION

Introduction

Very few herbicide options are currently available to growers for the control of over wintered broad leaved weeds in a crop of strawberries. Changes in legislation for clopyralid based products have meant that their use is now permitted only by an EAMU, issued for Dow Shield 400 (clopyralid), with application confined to the period from 1 March to 31 August. These changes, along with the widespread change from soil grown to substrate crop production, have meant that growers are often left with no option but to hand weed. Hand weeding is estimated to cost up to £1,200/ha per session and several sessions are often required in a single growing season of a strawberry crop, meaning that this is an expensive option. A considerable reduction in production costs may therefore be achieved by the ability to replace hand weeding by chemical weeding once, or even twice, per growing season.

Shark (carfentrazone ethyl) was used as an overall dormant season application in HDC project SF 91a. The Shark helped to remove a range of seedling and established broad leaved weeds growing around strawberry plants (Atwood and Irving, 2010). Two rates of Shark (0.33 and 0.8 L/ha) and three application dates were used (1 December, 28 January and 8 April). Shark applied in December and January did not cause any crown loss or injury to the strawberry plants. The April application of Shark did produce some scorching of strawberry foliage, however the affected plants fully recovered shortly after the damage was seen. No loss, death or damage to individual strawberry plant crowns, reduction in flower or berry numbers at the start (first pick) of harvest was seen. However, the crop was slightly thinner on one site of each crop row. American willowherb (*Epilobium ciliatum*) on one site was initially scorched and then effectively controlled by Shark. This trial's results indicated that American willowherb could be controlled by both rates of carfentrazone-ethyl (as Shark). No residues of carfentrazone-ethyl were found in the treated fruit collected during the first pick of the harvest.

During the first year of project SF 151, Shark was applied in March 2014 over established strawberry plants cv. Elegance towards the end of the crop's dormant period. Shark was applied at two rates (0.33 L/ha and 0.8 L/ha). Some initial scorching of the foliage of the treated strawberries was seen, however no lasting phytotoxic effects were observed and no differences between yield and fruit quality at harvest were seen. Both rates of Shark provided effective control of American Willowherbs and Chickweed (*Stellaria media*) that were present when this herbicide was applied. There was also some promising effects seen on groundsel (*Senecio vulgaris*). No residues were detected in fruit sent for analysis from the first harvest of the treated plants. This trial was dealt with in the year one report for this project and so will only feature in the grower summary in this final year report.

For the second trial, Shark was applied in August 2014 as an immediate post-harvest spray over a strawberry crop at two rates (0.33 L/ha and 0.8 L/ha) on a commercial farm in Cambridge. The third trial was for replication and was set up on two commercial fruit farms (one near Cambridge and one in Wisbech). A total dose of 0.8 L/ha of Shark was applied to this third trial; 0.4 L/ha immediately post-harvest in August 2014 and 0.4 L/ha prior to the onset of crop growth in March 2015.

The aim of SF 151 was to increase grower confidence with the rates and timing of application of Shark, when applied as an overall crop spray for post-emergence control of predominantly annual, but also some biennial and perennial broad-leaved weeds commonly found in the soil and substrate grown crops in the UK. The data collected on the crop safety of Shark and the residue data, obtained from fruit analysis, are being used to support an application for the Extension of Authorisation for Minor Use (EAMU) of carfentrazone ethyl (Shark) on strawberry.

The specific objectives of this project were to:

- Assess for effects on crop safety and yield
- Assess weed control efficacy

Materials and methods

The second trial, to test the effect of post-harvest application, was carried out using a strawberry plantation of the cv. Elsanta on a commercial farm in Cambridge. The crop was grown under a polythene clad polytunnel (Spanish tunnel) from planting in April 2014 until the end of its first harvest in July 2014.The tunnel cladding was then removed and the plants were left in the open over the autumn and winter. In its second year the tunnels were clad from April 2015, through harvest and were finally removed in September 2015. The crop was grown in coir substrate filled bags, laid down on polythene mulch covered raised beds. The crop was trickle irrigated and fertigated throughout both of its growing/cropping years.

A fully randomised block design was used for this trial which included four treatments (**Table 1**). Each treatment was replicated four times giving a total of 16 plots. Each plot was five meters long and one row wide. To avoid edge effects all assessments were confined to plants in the central three meters of each plot. All the treatments were applied immediately after harvest on the 22 July 2014. Shark applications were made using a water volume of 500 L water/ha and using an air assisted OPS knapsack sprayer and hand lance at two bar pressure and 04F110 nozzle. The trial area was managed according to the standard commercial practice of the host farm and so insecticides, fungicides and fertilisers were applied as and when necessary. Full crop husbandry records are detailed in appendix 2.

Table 1. Treatment list for post-harvest trial, applied on 22 July 2014 – Cambridge

Treatment number	Treatment	Active ingredient	Rate kg/ha or L/ha
1	Untreated	-	-
2	Hand weeded	-	Removal of all visible weeds in and around planting holes
3	Shark	60g/l carfentrazone-ethyl	0.33 L/ha
4	Shark	60g/l carfentrazone-ethyl	0.8 L/ha

Any damage to plants (phytotoxicity) caused by the treatments was assessed two and four weeks after the Shark was applied and then again as plant growth commenced in March 2015, April at flowering and also at harvest (**Table 2**). All plots were assessed, comparing the treated plots to the untreated controls and scored on a scale of zero to nine, where zero is a dead, seven is commercially acceptable and nine is a healthy plant equivalent to the untreated control. Photographs were taken to record symptoms of phytotoxicity.

The percentage weed coverage of the alleyways was assessed and the number of weeds in planting holes were counted. Weed assessments were carried out prior to treatment and then again at two and four weeks after treatment.

Plants were also assessed for the incidence of powdery mildew on three occasions; prior to treatment application and then at two and four weeks after treatment. On these occasions plants were also assessed to detect any adverse effects of Shark on crown health by recording the number of live crowns for five plants that were selected at random and located in the central three metres of each plot. The average number of live crowns per plant were then calculated.

All the fruit produced by plants in the trial was picked by farm staff. Picking took place on six occasions over a three week harvest. The fruit was graded as it was harvested into class one and waste fruit. The total weight and number of berries in class one and in waste were recorded for each plot.

On the first pick of fruit, a 1 kg bulked fruit sample was collected from the four replicated blocks for each of the two Shark treatments and the untreated control. These samples were sent for residue analysis for carfentrazone-ethyl at QTS Analytical Ltd.

Table 2. Dates and timings of assessments

Assessment number	Timing of assessment	Date of assessment
1	Prior to treatment	23/07/14
2	Two weeks after treatment	05/08/14
3	Four weeks after treatment	22/08/14
4	March – as growth commences	06/03/15
5	April/May – at flowering	22/04/15
6	Harvest assessments	03/06/15 - 26/06/15

In addition to the main post-harvest application of Shark, an additional trial was set up with two commercial sites (one near Cambridge and the other in Wisbech). These were set up primarily to provide samples of fruit from plants treated with Shark which could be submitted for analysis according to Good Laboratory Practice (GLP) protocols to identify any residues of carfentrazone-ethyl. This data was needed to support an application for Extension of Authorisation for Minor Use (EAMU). The June bearing strawberry varieties used for this trial were Elsanta at the site near Cambridge and Sonata at the Wisbech site. At the site near Cambridge the plants were being grown in coir in bags under Spanish polytunnels and at Wisbech the crop was grown in soil, unprotected. Water and nutrients were provided to the crop by trickle irrigation on both sites.

Each of these sites consisted of two treated plots 20 m long and two rows of strawberry plants wide and two untreated 20 m long plots, also two rows wide. There were two treatments, an untreated control and carfentrazone-ethyl (Shark). Shark was applied at 0.4 L/ha on two occasions to give a total dose of 0.8 L/ha (**Table 3**). Treatments were first applied post-harvest on 22 August 2014 and the second application was on 6 March 2015. Treatments were applied at a water volume of 500 L/ha using an air assisted OPS knapsack sprayer and hand lance at two bar pressure and 04F110 nozzle. These trials were set up purely to gather information on crop residues with no assessments of efficacy, crop safety or yield required.

Table 3. Treatment list for post-harvest and dormant season trial, applied on two occasions (22 August 2014 and 6 March 2015) - Cambridge and Wisbech

Treatment number	Treatment	Active ingredient	Rate kg/ha or L/ha
1	Untreated	-	-
2	Shark	60g/l carfentrazone-ethyl	0.4 L/ha

Results

Crop safety

Shark, at both the higher and lower rate in the main post-harvest trial, caused some scorching of the fully expanded mature foliage that was present at the time of the application. This scorching was recorded two and four weeks after the Shark had been applied (**Table 4**). The symptoms of damage were seen as minor spotting and scorching on the older leaves in the upper part of the foliar canopies of the strawberry plants (**Figures 1 & 2**). These symptoms were not present in the untreated plants (**Figures 3 & 4**). Newly emerged foliage displayed very little damage. Strawberry plants treated with the higher rate of Shark (0.8 L/ha) showed more severe phytotoxicity symptoms than those treated with the lower rate of Shark (0.33 L/ha).There was no sign of any additional phytotoxicity (e.g. by translocation), and very little of that produced by the spray applications in July 2014 was observed when the plants were next assessed in March 2015, i.e. soon after they started back into growth after winter. By the fourth assessment, at flowering, all of the strawberry plants had fully recovered (**Figure 5**).

Table 4. Mean phytotoxicity results for, post-harvest trial, from assessments carried out at two and four weeks after treatment, as growth commenced, at flowering and prior to harvest – Cambridge post-harvest trial

Treatment	2 weeks after treatment	4 weeks after treatment	As growth commenced	At flowering	Prior to harvest
1	9.0	9.0	9.0	9.0	9.0
2	9.0	9.0	9.0	9.0	9.0
3	7.5	7.8	8.9	9.0	9.0
4	5.5	6.8	9.0	9.0	9.0
P value	<0.001	<0.001	NS	NS	NS
l.s.d. (d.f. 9)	0.653	0.596	0.199	NS	NS

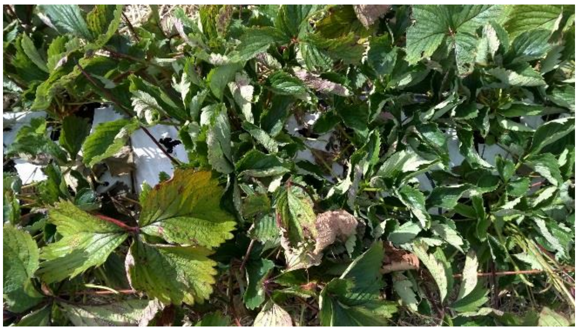

Figure 1. Untreated strawberry plant four weeks after treatment (post-harvest trial Cambridge)

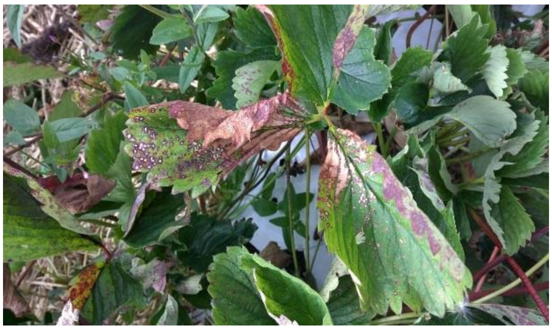

Figure 2. Scorched strawberry plant four weeks after being treated with Shark 0.8 L/ha (post-harvest trial Cambridge)

Figure 3. Healthy untreated strawberry plants at two weeks after treatment (post-harvest trial Cambridge)

Figure 4. Scorched strawberry plants treated with 0.8 L/ha Shark at two weeks after treatment (post-harvest trial Cambridge)

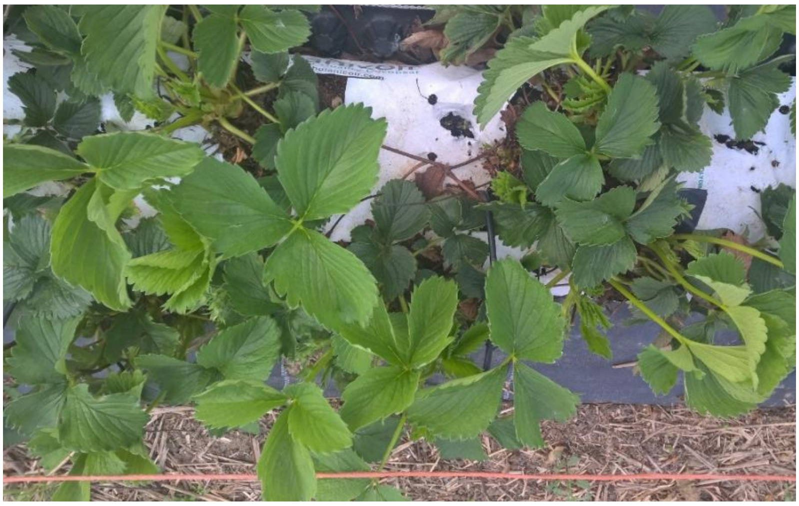

Figure 5. Recovered Shark (0.8 L/ha) treated strawberry plants in April 2015 (post-harvest trial Cambridge)

There were no differences observed between the different treatments for the number of live crowns per plant in the post-harvest trial (**Table 5**).

Table 5. Mean number of live crowns per plant assessed two and four weeks after treatment **–** Cambridge post-harvest trial

Treatment	2 weeks after treatment	4 weeks after treatment
Untreated control	2.0	2.3
Hand weeded	2.0	2.2
Shark (0.33L/ha)	2.2	2.3
Shark (0.8L/ha)	2.2	2.1
P value	NS	NS
l.s.d. (d.f. 9)	0.346	0.261

Weed control

At the time when treatments were applied, there were very few weeds present in the planting holes of the strawberry plants in the post-harvest application trial (**Table 6**). Two weeks after treatment both the planting holes of the plots treated with Shark (0.33 L/ha and 0.8 L/ha) and the hand weeded plots had significantly fewer weeds compared to the untreated plots. By four weeks, Shark at the lower rate (0.33L/ha) was the only treatment to have significantly fewer weeds in planting holes compared to the hand weeded treatment.

Prior to treatment there were more weeds present in the alleyways than there were in the planting holes. The weed population consisted mainly of docks, groundsel, American willowherbs, small nettle (*Urtica urens*), sow thistle (*Sonchus oleraceus*) and common chickweed. There were no significant differences related to any of the treatments for percentage weed cover in alleyways after treatment (**Table 7**). Shark caused severe scorching to certain weed species such as sow thistle and dock (*Rumex obtusifolius*) (**Figures 6 & 7**) and slightly scorched other species e.g. willowherb and chickweed. However, the species that were only slightly scorched grew away from the initial damage. Shark had very little effect on groundsel or black nightshade (*Solanum nigrum*) (**Figure 8**).

Table 6. Number of weeds in strawberry planting holes prior to treatment, two weeks and four weeks after treatment – Cambridge post-harvest trial

Treatment	Prior to treatment	2 weeks after treatment	4 weeks after treatment
Untreated control	1.0	4.0	1.8
Hand weeded	1.0	1.0	2.3
Shark (0.33L/ha)	0.0	0.8	0.5
Shark (0.8L/ha)	0.0	0.8	1.3
P value	NS	0.032	0.047
l.s.d. (d.f. 9)	1.006	1.622	1.200

Table 7. Percentage weed cover in alleyway measured prior to treatment, two and four weeks after treatment – Cambridge post-harvest trial

Treatment	Prior to treatment	2 weeks after treatment	4 weeks after treatment
Untreated control	2.5	10.8	13.0
Hand weeded	8.8	2.5	8.8
Shark (0.33L/ha)	2.8	8.3	10.8
Shark (0.8L/ha)	4.5	5.5	7.5
P value	NS	NS	NS
l.s.d. (d.f. 9)	6.92	11.67	13.37

Figure 6. Partly scorched dock two weeks after treatment –Shark (0.8 L/ha) Cambridge post-harvest trial

Figure 7. Scorched sow thistle four weeks after treatment – Shark (0.8 L/ha) Cambridge post-harvest trial

Figure 8. Healthy black nightshade four weeks after being treated with Shark (0.33 L/ha) Cambridge post-harvest trial

Powdery mildew

Assessments were made of percentage of plants affected by powdery mildew prior to treatment application. Assessments were also made two and again at four weeks after treatment in the post-harvest trial in Cambridge (**Table 8**). There were no significant differences between plants treated with Shark (0.33 L/ha or 0.8 L/ha) or untreated plants in terms of powdery mildew incidence.

Table 8. Percentage of plants affected by powdery mildew prior to treatment, two weeks after treatment and four weeks after treatment- Cambridge post-harvest trial

Treatment	Prior to treatment	2 weeks after treatment	4 weeks after treatment
Untreated control	57.5	82.5	72.5
Hand weeded	52.5	87.5	72.5
Shark (0.33L/ha)	50.0	82.5	70.0
Shark (0.8L/ha)	66.2	90.0	78.8
P value	NS	NS	NS
l.s.d. (d.f. 9)	19.78	10.58	13.87

Harvest assessments and residue analysis

The class one yield was significantly lower for the plots treated with Shark (0.8 L/ha) than any of the other treatments in the post-harvest trial near Cambridge (**Table 9**). Plots treated with Shark at the lower (0.33 L/ha) rate did not have significantly lower class one yields compared to the untreated plots or the hand weeded plots. Waste fruit included strawberries that were either rotten, malformed, over ripe, too small, damaged by pests or pickers, or were affected by powdery mildew. There were no differences between the numbers of strawberries in the waste category for any of the different treatments. There were also no differences between treatments for average berry weights.

Table 9. Assessments carried out over the harvest period and included class 1 yield, waste yield and average berry weight – Cambridge post-harvest trial

Treatment	Class 1 yield g/plant	Waste yield g/plant	Average berry weight (g)
Untreated	391.97	35.60	14.88
Hand weeded	443.13	28.91	16.76
Shark 0.33 L/ha	435.49	28.04	17.56
Shark 0.8 L/ha	280.64	33.76	15.73
P value	0.005	NS	NS
l.s.d. (d.f. 9)	81.20	17.48	2.48

No formal assessments were made of the final trial (located on two sites) where Shark was applied on two occasions, post-harvest and in the dormant season. This trial was set up to provide fruit to be sent for residue analysis according to Good Laboratory Practice (GLP). This data was required to support an application for an Extension of Authorisation for Minor Use. No residues were found in the strawberries that were harvested in this trial.

Discussion

Shark applied at both rates, 0.33 L/ha and 0.8 L/ha, caused some scorch to the mature leaves of the strawberry plants in the post-harvest trial which could be seen two and four weeks after herbicide application. Young leaves emerging post application of Shark were unaffected and all plants had recovered by March 2015. Plots treated with the higher rate of Shark (0.8 L/ha) had a significantly lower yield of class one strawberries than the other treatments which could be due to the more severe scorching on the leaves reducing the level of photosynthesis of the plants or an effect on the metabolism. Shark (0.33 L/ha and 0.8 L/ha) had no effect on the other variables measured at harvest i.e. waste yield or average berry weight. These results suggest that the use of carfentrazone–ethyl as Shark at 0.33 L/ha and 0.8 L/ha could offer a reasonably safe option for post emergence broad-leaved weed control for strawberries when applied during the late winter, i.e. prior to the onset of strawberry plant growth, or at the lower rate as an immediate post-harvest treatment.

At two weeks after application, both rates of Shark had reduced the number of weeds found in planting holes. The lower rate of Shark (0.33 L/ha) also had a significantly lower number of weeds present four weeks after spraying. However, neither rate of Shark had a significant effect on the percentage weed cover in the alleyways. There was a healthy covering of grass in alleyways and Shark is known to have little effect on species of grasses.

Shark at both rates caused quite severe scorching on dock and sow thistle, however most weeds recovered from scorch that was seen at the two weeks after treatment assessment. Some scorch was seen on other weeds such as chickweed and willowherb where good contact had been made. In this trial, groundsel and black nightshade were untouched by the Shark. No individual species were completely eliminated by either rate of Shark in the post-harvest trial near Cambridge.

After the four week assessment no further assessments of weeds were carried as Shark is a contact herbicide and, therefore, it wouldn't be expected to have had any residual effect on the weeds.

Conclusions

The use of carfentrazone-ethyl (Shark) as an over the crop spray post-harvest application appeared to have no lasting visible phytotoxicity effects on strawberry plants. Any initial scorch that was caused by both rates of Shark was confined to the older leaves in the crop canopy where Shark came into contact with the foliage. All new growth that came through after the Shark had been applied was healthy. However class one fruit yield the following year did appear to be reduced by Shark applied at the higher rate (0.8 L/ha) post-harvest. Shark didn't appear to have any effect on the amount of waste fruit produced or the average berry weight of treated plants when applied at both the higher and lower rates post-harvest. Although work in year one of this project (and SF 91 and 91a) has shown that higher rate Shark applications are adequately safe when applied during the dormant season, the use of Shark at the higher rate post-harvest would appear to be inadvisable.

Both 0.33 L/ha and 0.8 L/ha of Shark showed promising efficacy when good coverage was achieved and where the Shark came into contact with new soft growth of weeds. The best effects of Shark were seen on dock and sow thistle when it was applied at the higher rate (0.8 L/ha).

No residues were detected in the fruit that was sent for residue analysis from the first pick in the post-harvest application trial (near Cambridge). Neither were residues detected in fruit that was harvested from the two sites that were set up purely for sending fruit off for residue analysis using Good Laboratory Practice (GLP) protocols. These results show that the fruit treated by both rates of Shark would be suitable for marketing.

All results obtained from the post-harvest application trial, and the extra trial that was set up on two sites purely for residue analysis, prove the safety and efficacy of Shark when applied as a post-harvest and dormant season application at a total dose rate of 0.8 L/ha. These results can now be used to support an Extension of Authorisation for Minor Use (EAMU) for carfentrazone-ethyl (as Shark) on a crop of strawberries. This EAMU will provide growers with another useful option for post-emergence broad leaved weed control in a crop of strawberries and should help growers reduce costs by reducing the need for expensive and time consuming hand weeding.

References

Atwood J. and Irving R (2010) Strawberry: Evaluation of herbicides for use in bed systems. HDC report SF 91 and SF 91a

Appendices

Appendix 1: Trial plan for post-harvest trial near Cambridge

Block	Plot	Trt.
1	1	2
1	2	4
1	3	3
1	4	1

Block	Plot	Trt.
2	5	2
2	6	1
2	7	4
2	8	3

Block	Plot	Trt.
3	9	1
3	10	3
3	11	2
3	12	4

Block	Plot	Trt.
4	13	4
4	14	1
4	15	3
4	16	2

Appendix 2: Trial plan for post-harvest and dormant season application trials set up on two locations (near Cambridge and Wisbech) for residue analysis

Plot	1	2
Trt.	1	2

Appendix 3: Crop husbandry records (Outdoor Strawberry, post-harvest trial)

Date	Product	Rate
17/02/14	Devrinol – napropamide Flexidor – isoxaben Reglone – diquat	7.0 L/ha inter rows 2.0 L/ha no crop 2.0 L/ha no crop

Date	Product	Rate
31/03/14	Venzar – lenacil Shark – carfentrazone-ethyl Harvest - glufosinate-ammonia SPO 57 – wetter	5.0 L/ha overall 0.33 L/ha overall 5.0 L/ha no crop 2.0 L/ha no crop
03/05/14	Paraat - dimethomorph	3.0 kg/ha
05/05/14	Rovral – iprodione Triptam – thiram Maxicrop – foliar feed Hortiphyte - foliar feed	1.0 kg/ha 2.0 kg/ha 4.0 L/ha 4.0 L/ha
09/05/14	Gusto – metaldehyde 3%	11.0 kg/ha
13/05/14	Pyrinex – chlorpyifos Maxicrop - foliar feed	1.0 L/ha 4.0 L/ha
17/05/14	Fortress – quinoxyfen Switch - cyprodinil and fludioxonil Envidor – spirodiclofen Maxicrop - foliar feed	0.25 L/ha 1.0 L/ha 0.4 L/ha 4.0 L/ha
24/05/14	Systhane – myclobutanil Scala – pyrimethanil Calypso – thiacloprid Maxicrop - foliar feed Seniphos – foliar feed	0.45 L/ha 1.5 L/ha 0.25 L/ha 4.0 L/ha 3.0 L/ha
30/05/14	Rovral - iprodione	1.0 kg/ha

Date	Product	Rate
	Amistar - azoxystrobin Sulphur Maxicrop - foliar feed	1.0 L/ha 1.5 L/ha 4.0 L/ha
06/06/14	Systhane - myclobutanil Teldor – fenhexamid Calypso – thiacloprid Maxicrop - foliar feed	0.45 L/ha 1.0 kg/ha 0.25 L/ha 4.0 L/ha
11/06/14	Systhane - myclobutanil Amistar - azoxystrobin Serenade - *Bacillus subtilis* Maxicrop - foliar feed Seniphos - foliar feed	0.45 L/ha 1.0 L/ha 10.0 L/ha 4.0 L/ha 3.0 L/ha
16/06/14	Serenade - *Bacillus subtilis* Sulphur Seniphos - foliar feed Maxicrop - foliar feed SB Plant Invigorator - urea	10.0 L/ha 1.5 L/ha 3.0 L/ha 4.0 L/ha 2.0 L/ha
19/06/14	Potassium bicarb Activator 90 - wetter	10 kg/ha 1.0 L/ha
23/06/14	Nimrod - bupirimate Teldor - fenhexamid Sulphur Serenade - *Bacillus subtilis* Maxicrop - foliar feed Seniphos – foliar feed	1.4 L/ha 1.0 L/ha 1.5 L/ha 10.0 L/ha 4.0 L/ha 3.0 L/ha

Date	Product	Rate
28/06/14	Serenade - *Bacillus subtilis* Sulphur Seniphos - foliar feed Maxicrop - foliar feed SB Plant Invigorator - foliar feed	10.0 L/ha 1.5 L/ha 3.0 L/ha 4.0 L/ha 2.0 L/ha
01/07/14	Potassium Bicarb Activator 90 - wetter	10.0 kg/ha 1.0 L/ha
05/07/14	Nimrod - bupirimate Teldor - fenhexamid Sulphur Serenade - *Bacillus subtilis* Maxicrop - foliar feed Seniphos - foliar feed	1.4 L/ha 1.0 kg/ha 1.5 L/ha 10.0 L/ha 4.0 L/ha 3.0 L/ha
09/07/14	Foliar Supreme – foliar feed Bio18 - foliar feed Hortiphyte – foliar feed Seniphos - foliar feed	4.0 L/ha 2.0 L/ha 4.0 L/ha 3.0 L/ha
22/07/14	Corbel - fenpropimorph	1.0 L/ha
26/07/14	Triptam – thiram Rovral – iprodione Fortress - quinoxyfen	2.5 kg/ha 1.0 kg/ha 0.25 L/ha
14/08/14	Fenomenal - fenamidone and fosetyl-aluminium	4.5 kg/ha
19/08/14	Corbel – fenpropimorph DP 98 - foliar feed	1.0 L/ha 4.0 L/ha

Date	Product	Rate
27/08/14	Systhane – myclobutanil Amistar – isoxystrobin Rovral – iprodione Hallmark - lambda-cyhalothrin Maxicrop - foliar feed	0.45 L/ha 1.0 L/ha 1.0 kg/ha 0.125 L/ha 4.0 L/ha
18/09/14	Hortiphyte - foliar feed	10.0 L/ha
30/09/14	Potassium Bicarb Activator 90 - wetter	10.0 kg/ha 1.0 L/ha
17/10/14	Hortiphyte – foliar feed	10 L/ha
17/02/15	Devrinol – napropamide Stomp aqua – pendimethalin Reglone – diquat Activator 90 - wetter	7.0 L/ha alleys and leg rows 3.3 L/ha alleys and leg rows 2.0 L/ha alleys and leg rows 1.0 L/ha alleys and leg rows
19/02/15	Paraat - dimethomorph	3.0 kg/ha
10/03/15	Gusto - metaldehyde 3%	11.0 kg/ha
08/04/15	Rovral - iprodione Cyren - chlorpyrifos Hallmark - lambda-cyhalothrin Hortiphyte – foliar feed	1.0 kg/ha 1.0 L/ha 0.125 L/ha 10.0 L/ha
10/04/15	Fortress – quinoxyfen Teldor – fenhexamid Maxicrop – foliar feed	0.25 L/ha 1.0 kg/ha 4.0 L/ha

Date	Product	Rate
05/06/15	Serenade – bacillus subtilis Sulphur Maxicrop – foliar feed Seniphos – foliar feed SB Plant Invigorator – foliar feed	10.0 L/ha 1.5 L/ha 4.0 L/ha 3.0 L/ha 2.0 L/ha
09/06/15	Nimrod - bupirimate Teldor - fenhexamid Serenade - *Bacillus subtilis* Sulphur Maxicrop – foliar feed Seniphos – foliar feed	1.4 L/ha 1.0 kg/ha 10.0 L/ha 1.5 L/ha 1.5 L/ha 3.0 L/ha
17/06/15	Serenade - *Bacillus subtilis* Sulphur SB Plant Invigorator – foliar feed Seniphos – foliar feed Maxicrop – foliar feed	10.0 L/ha 1.5 L/ha 2.0 L/ha 3.0 L/ha 1.5 L/ha
24/06/15	Potassium Bicarb Activator 90 - wetter	10 kg/ha 1.0 L/ha
08/07/15	Equity – chlorpyrifos Codacide oil	1.0 L/ha 2.5 L/ha

Date	Product	Rate
01/09/15	Harvest - glufosinate-ammonium Codacide oil	12.5 L/ha inter row and leg row only 12.5 L/ha inter row and leg row only
10/09/15	Borneo – etoxazole Clayton Abba – abamectin SPO 58 - wetter	0.35 L/ha 0.5 L/ha 1.0 L/ha
14/09/15	Paraat - dimethomorph	3.0 L/ha
25/09/15	Corbel - fenpropimorph	1.0 L/ha
21/09/15	Hortiphyte – foliar feed	10.0 L/ha