Project title:	Strawberry: Investigating rates and application timing of carfentrazone-ethyl (Shark) as a dormant season herbicide to support extension of use application
Project number:	SF 151
Project leader:	Harriet Roberts, ADAS UK Ltd
Report:	Annual report, December 2014
Previous report:	None
Key staff:	Janet Allen Emma Worrall Steve Darlington
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Date project commenced:	1 February 2014
Date project completed (or expected completion date):	31 September 2015

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

AUTHENTICATION

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.

Harriet Roberts

Horticultural consultant

ADAS UK Ltd.

Signature:  Date: 19th December 2014

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GROWER SUMMARY

Headline

- Following the overall application of two rates of Shark (carfentrazone-ethyl) as a dormant season spray to a strawberry crop to control existing weeds, no adverse effects were observed on crop growth or yield.

Background and expected deliverables

There are currently few options for the post-emergence control of broad leaved weeds in newly planted or established strawberries. Products containing diquat or glufosinate-ammonium are used as spot or directed (shielded) applications to remove weeds growing in the alleyways between crop beds or rows, but only clopyralid (Dow Shield 400) can be applied overall for the control of seedling and established broad leaved weeds in outdoor strawberries. However clopyralid is primarily used to control composite weed species and application (by EAMU) is restricted to the period 1 March to 31 August, meaning there are now no options for the overall post-emergence weed control in the strawberry crop rows outside this period. Because of the restrictions to clopyralid use and its limited range of activity, hand weeding is often the only option for the post emergence control of broad-leaved weeds growing in crop rows. It is estimated that the cost of hand weeding in strawberry plantations per session could be up to £1,200/ha. A typical strawberry crop grown in the soil or in substrate is expected to require several sessions of hand weeding during its life.

Carfentrazone-ethyl (Shark) has previously been appraised both for strawberry runner control and as a dormant season spray over the top of the crop (SF 91 and 91a). In both cases very little lasting damage to strawberry plants occurred. These results indicated that carfentrazone-ethyl could be considered as an overall crop spray in strawberries, thereby extending the range of weed species controlled and the period when overall application of herbicides can be made. To do this, further trials are required to determine the optimum rates and timing of application to demonstrate safety to the crop. Such trials will also assess efficacy of control for problem weeds such as willowherb, cleavers, mallow and polygonum

species. The work will include assessments of weed control in planting holes, both as a post-harvest spray and also in the dormant season.

The aim of this project was to increase confidence in the timing and rates of application of carfentrazone-ethyl (Shark) as an overall crop spray to strawberry crops in the dormant season, to control over-wintering weeds in and around strawberry plants. The results could be used to support an EAMU application.

Summary of the project and main conclusions

This trial was carried out on a commercial farm in a crop of Elegance which was protected by a Spanish style polytunnel. The crop was entering its second (main season) cropping year and was grown in coir substrate bags placed down on raised beds. The plots chosen were known to carry a varied but uniform weed population typical for strawberry. The treatments applied were carfentrazone-ethyl used at 0.33 L/ha or 0.8 L/ha, in 500 L water/ ha compared with a hand weeded and an untreated control.

The trial was set up in a fully randomised block design with four fold replication. Each plot comprised a three metre long run of row of coir filled bags and consisted of approximately 30 plants. The treatments were applied once on 19th February 2014, when the crop was fully dormant, using an air assisted OPS knapsack sprayer and lance.

Weed assessments were made before any treatments were applied. The plots were assessed both for crop damage and weed presence some two, four and eight weeks after treatment and then again at harvest.

All fruit was harvested by farm staff over a three week period, picking class one, class two and waste fruit separately, whilst recording fruit yield and number of berries in each category for each plot.

Despite some initial scorching of overwintered green leaves (**Figure 1**). Using carfentrazone-ethyl (Shark) as an overall dormant season spray, appeared to have no lasting phytotoxic effects on the strawberry plants or on yield or quality of fruit produced by the treated plants at harvest **(Table 1).**

Whilst no statistically significant effects were seen with either rate of Shark in terms of weed control, this was due to a low weed population found in the trial area in this 2014 season. Both rates of Shark did show promising herbicide efficacy against willowherb and chickweed, with both having some effect on groundsel. No residues were detected on fruit from the first harvest.

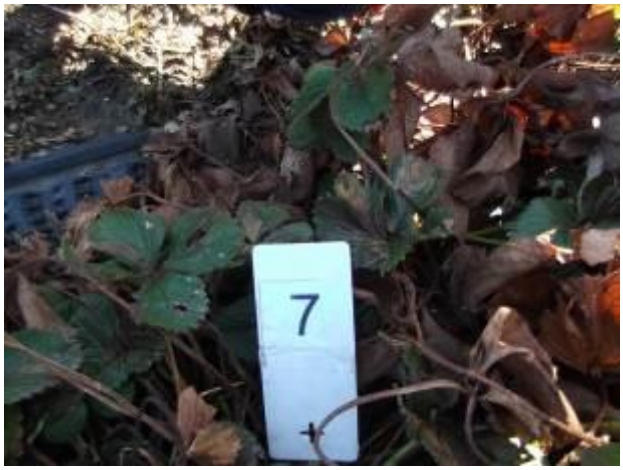

Figure 1. Scorching to plants treated with Shark (0.8 L/ha) was seen two weeks after treatment

Table 1. Results of dormant season applications on crop safety 2 and 8 weeks after application, weed control 2 weeks after application and marketable yield – Cambridge 2014. Phytotoxicity scored on a 0-9 scale where 0 is plant death and 9 in no effect.

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

In the second part of the trial, the safety of carfentrazone-ethyl (Shark) applied overall immediately post-harvest is being assessed. Application was made in September 2014 to a crop of Elsanta, planted as cold stored runners in coir filled bags in April 2014. Crop safety and effects on yield will be assessed in spring/summer 2015 and the results presented in the final report due in September 2015. In an additional area, Shark has been applied to larger (20 m^2) plots from which residue samples will be taken and analysed according to Good laboratory Practice (GLP) protocols in order to support an EAMU application.

Financial benefits

It is estimated that removal of weeds by hand could cost up to £1,200/ha per weeding session and typically, an individual plantation (either soil or substrate grown) may require weeding several times during its life. It can be expected that an increase in the options available to commercial strawberry growers for the post emergence control of weeds in the planting holes of overwintered strawberry beds, could lead to savings in excess of £2,000 per hectare.

Action points for growers

- For growers to benefit from the results of this work, an EAMU would be required for carfentrazone-ethyl (Shark).
- Trials work under this project (SF 151) is continuing into 2015 to assess the safety of a post-harvest application and to provide further residue data for an EAMU application.

SCIENCE SECTION

Introduction

Currently there is a very limited number of contact herbicide options for the post emergence control of winter germinated broad leaved weeds in the crop rows of strawberries, both in soil and substrate. This has been further complicated with the changes in approval for some products. For example Dow Shield (clopyralid) can no longer be used between the end of August and the beginning of March. The new restrictions on the use of Dow Shield, combined with a limited weed control spectrum, means that hand weeding becomes the only real option available for the control of weeds. It is estimated that hand weeding costs could be up to £1,200/ha per weeding session and often several sessions are required. Savings, by eliminating or reducing the need for hand weeding, could amount to greater than £2,000/ha.

AHDB Horticulture project SF 91a evaluated the potential for using Shark (carfentrazone-ethyl) as an overall dormant season treatment to selectively clean up existing weeds in plastic mulched beds (Atwood and Irving 2010). The trial looked at dormant season overall application, applied at two rates (0.33 and 0.8 L/ha) and three application timings (1 December, 28 January and 8 April) to strawberries grown in plastic covered raised soil beds. Results showed that the treatments applied in December and January 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 or flowers or any 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 and dandelions present at one site were scorched and effectively controlled. The lower rate was as effective as the higher rate and no residues were found on fruit from samples taken from the first pick.

Unfortunately, since the completion of the SF 91a trial, no application for EAMU has gone forward for Shark. As no other herbicide has become available to control germinated weeds within the crop in this way, carfentrazone-ethyl would be an enormously useful active to have available for use in this crop.

Aim and objectives

The aim of this project was to increase confidence in timing and rates of use of Shark (carfentrazone-ethyl) as an over the crop dormant season spray for the control of weeds in the planting holes of both soil and substrate grown crops in order to support an application for extension of authorisation for minor use (EAMU). The first year of this project looked to test two rates of Shark (0.33 L/ha and 0.8 L/ha) to determine the safety of using it as a dormant season herbicide application on a June bearer crop.

The specific objectives of this trial were to:

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

Materials and methods

The trial was held on a commercial fruit farm in Cambridge, on strawberry cv. Elegance planted in May 2013. The crop was protected by a polytunnel and was entering its second/main season cropping year. The crop was grown in coir substrate grow bags with trickle irrigation and fertigation.

A fully randomised block design was used for this trial. There were four treatments (Table 1) which were replicated four times giving a total of 16 plots. The plot size was 5 m long by one row with just the central 3 m of the plot being assessed to avoid edge effects. All treatments were applied to the plots on 19 February 2014 at a volume of 500 L water/ha using an air assisted OPS knapsack sprayer and hand lance at 2 bar pressure and 04F110 nozzle. The trial areas were managed as far as possible according to the standard commercial practice practiced by the host farm, including residual and contact herbicides, insecticides, fungicides and fertilisers applied as and when necessary. Full crop husbandry records are detailed in Appendix 1.

Table 1. Treatment list – Applied 19 February 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 phytotoxic damage to plants caused by the treatments applied was assessed two, four and eight weeks after the herbicides were applied and then again at harvest (Table 2). All plots were assessed, comparing the treated plots to the untreated controls and scoring on a scale of zero to nine, where zero is dead, seven is commercially acceptable and nine is a healthy plant/equivalent to the untreated control treatment. A camera was used to photographically record symptoms of phytotoxicity. Assessments were carried out of the percentage weed coverage of the alleyways and also the number of planting holes of the bags in each plot with weeds within them was counted. Weed assessments were carried out prior to treatment and then two, four and eight weeks after treatment.

All fruit was harvested by farm staff on six occasions over three weeks, starting from the first pick. Class 1, Class 2 and waste fruit were harvested, the weight and number of berries in these categories being recorded for each plot.

A 1 kg bulked fruit sample across the four replicated blocks for each of the two Shark treatments and untreated control were sent for residue analysis from the first pick of fruit to QTS Analytical Ltd.

Table 2. Dates and timings of assessments

Assessment number	Timing of assessment	Date of assessment
1	Prior to treatment	19/02/14
2	Two weeks after treatment	05/03/14
3	Four weeks after treatment	18/03/14
4	Eight weeks after treatment	16/04/14
5	Prior to harvest	04/06/14
6	Harvest assessments	04/06/14 - 12/06/14

Results

Crop safety

Strawberry plants treated with both of the rates of Shark displayed some symptoms of phytotoxicity when assessed two and four weeks after treatment (Table 3). The symptoms consisted of some minor spotting and scorching of the leaves (Figures 2, 3 and 5). As expected the phytotoxicity scores for the lower rate of Shark (0.33 L/ha) were less than for the higher rate of Shark (0.8 L/ha). However, eight weeks after treatment the affected plants had fully recovered to the extent that no phytotoxicity damage could be seen (Figure 6).

Table 3. Mean phytotoxicity results from assessments carried out at two, four and eight weeks after treatment

Treatment	Phytotoxicity 2 weeks after treatment *	Phytotoxicity 4 weeks after treatment *	Phytotoxicity 8 weeks after treatment *
Untreated	9.0	9.0	9.0
Hand weeded	9.0	9.0	9.0
Shark 0.33 L/ha	8.0	7.0	9.0
Shark 0.8 L/ha	6.5	5.8	9.0
P value	<0.001	<0.001	NS
l.s.d. (d.f. 9)	0.884	0.766	NS

* 0 = dead; 7 = commercially acceptable; 9 = healthy plant/equivalent to the untreated control treatment

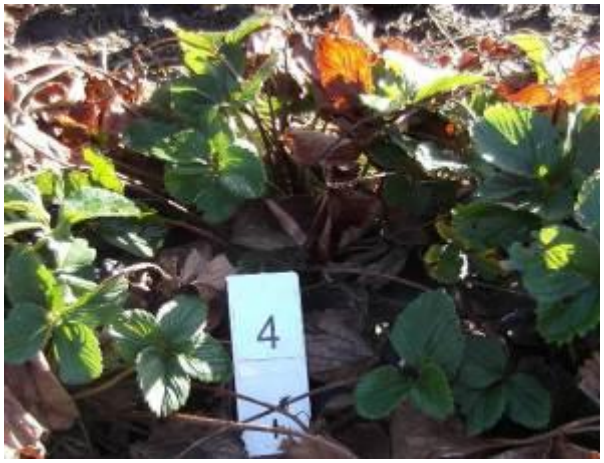

Figure 1. Untreated strawberry plants at first assessment two weeks after treatment

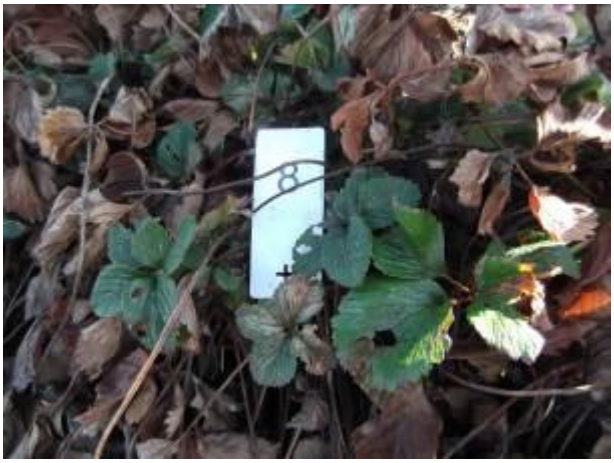

Figure 2. Scorch on strawberry plants that were treated with Shark (0.33 L/ha) two weeks after treatment.

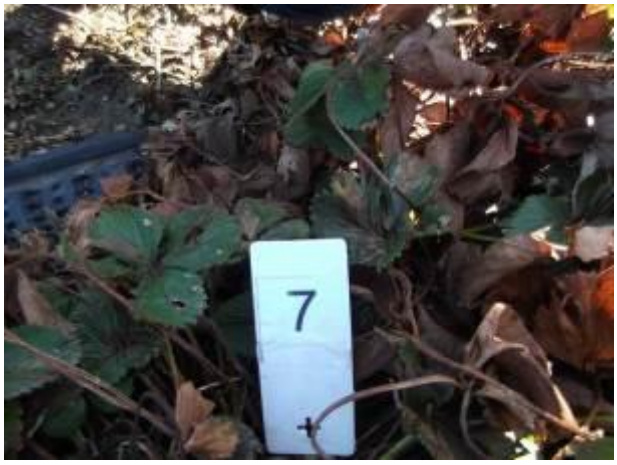

Figure 3. Phytotoxicity on plants treated with (0.8L/ha) of Shark, two weeks after treatment

Figure 4. Untreated strawberry plants four weeks after treatment

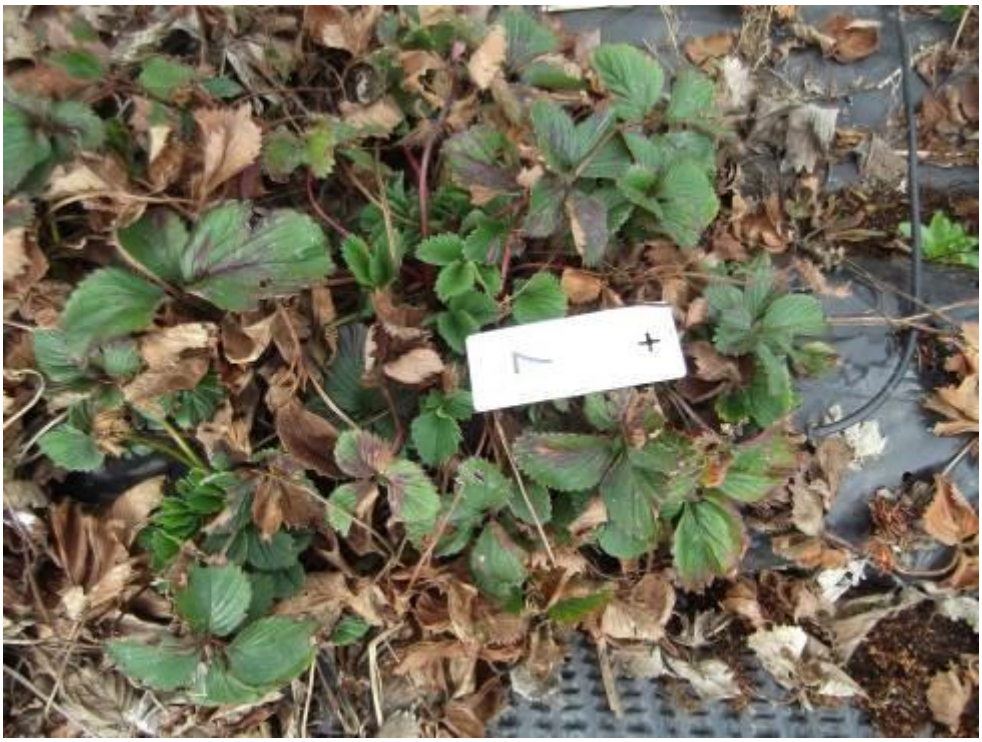

Figure 5. Plants treated with (0.8L/ha) of Shark showing phytotoxicity effects four weeks after treatment

Figure 6. Shark (0.33L/ha) treated plot 8 weeks after treatment

Weed control

There were few weeds present in the planting holes at the beginning of the trial. Through the growing season the number of weeds in planting holes did not differ significantly between any of the four treatments (Table 4). Weed control achieved in the alleyways did show differences, but only with the hand weeded plots was there any significant difference from the untreated control. Carfentrazone-ethyl (Shark) is contact acting so no control of weeds that emerged post application would be expected. The weed population present consisted of predominantly groundsel, American willowherb and chickweed and Shark caused significant scorch of all of these species and eventually killed the willowherb but did not completely kill other species (Figures 7-10).

Table 4. Number of weeds in strawberry planting holes prior to treatment, two weeks, four weeks and eight weeks after treatment – Cambridge 2014

Treatment	Prior to treatment	2 weeks after treatment	4 weeks after treatment	8 weeks after treatment
Untreated control	0.25	1.75	2.00	1.50
Hand weeded	1.75	0.50	2.00	5.50
Shark (0.33L/ha)	3.00	3.00	4.75	4.75
Shark (0.8L/ha)	2.25	2.25	4.25	4.25
P value	NA	NS	NS	NS
l.s.d. (d.f. 9)	NA	2.933	4.061	4.988

Table 5. Percentage weed cover in alleyway measured prior to treatment and then two, four and eight weeks after treatment – Cambridge 2014

Treatment	Prior to treatment	2 weeks after treatment	4 weeks after treatment	8 weeks after treatment
Untreated control	21.2	20.0	16.2	17.5
Hand weeded	42.5	0.5	0.9	2.2
Shark (0.33L/ha)	33.8	14.5	12.0	24.0
Shark (0.8L/ha)	30.0	12.5	12.8	18.8
P value	NS	0.017	0.045	0.026
l.s.d. (d.f. 9)	29.96	10.89	10.61	13.35

Figure 7. Willowherb, treated with Shark (0.33 L/ha), two weeks after treatment

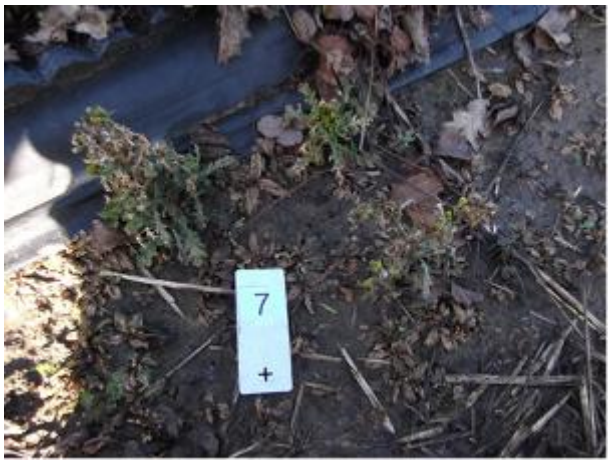

Figure 8. Willowherb and groundsel, treated with Shark (0.8 L/ha), two weeks after treatment.

Treatment	Average marketable yield g/plant	Average % Marketable fruit	Average berry weight (g)
Untreated	700.31	88.83	14.29
Hand weeded	802.03	90.07	15.08
Shark 0.33 L/ha	774.96	90.10	14.65
Shark 0.8 L/ha	807.84	90.89	14.34

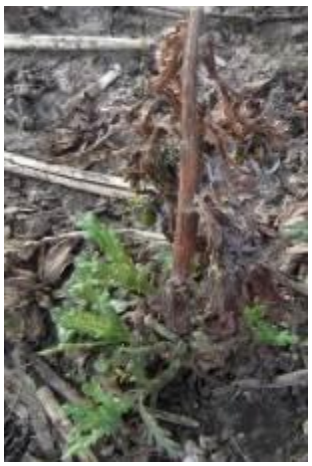

Figure 9. Scorched groundsel, Shark (0.33 L/ha), at four weeks after treatment

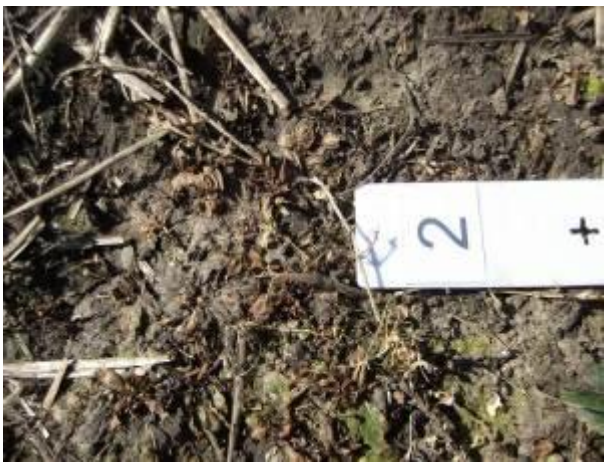

Figure 10. Effect of Shark (0.8 L/ha) in alleyway at four weeks after treatment, chickweed controlled

Harvest assessments and residues

There were no statistically significant differences between treatments of any of the measurements taken at harvest (**Table 6**). Waste fruit included strawberries that were rotten, over-ripe, malformed, too small, damaged by pests, damaged by pickers or were affected by powdery mildew.

P value	NS	NS	NS
l.s.d. (d.f. 9)	164.5	3.218	0.597

Table 6.

No residues of carfentrazone-ethyl were detected in fruit sent off for residue analysis by QTS analytical Ltd.

Discussion

Shark applied at 0.33 and 0.8 L/ha did cause some minor scorch to the overwintered green leaves of the target strawberry plants, which was visible at two and four weeks after treatment. New leaves emerging after treatment were not affected and all plants grew away with no differences in vigour being observed. The Shark also had no effect on any of the variables measured at harvest i.e. marketable yield, % marketable yield or average berry weight. These results suggest that Shark at both of the above rates of use is safe to use on strawberry plants as an over-the-crop dormant season spray.

Neither rate of Shark caused any significant reduction in the number of weeds in planting holes, nor the percentage weed cover in alleyways. However, few weeds were established when the Shark treatment was applied and since Shark is a contact herbicide it requires foliage present in order to work.

Two weeks after treatment both rates of Shark had scorched groundsel, willowherb and chickweed that had been present. The effects of the application of the residual herbicide propyzamide (Solitaire), applied by the grower host in November 2013 as an alleyway spray for the control of grass weeds and chickweed, could be seen at this assessment.

Four weeks after Shark treatment had been applied good control of willowherb had been obtained where good spray coverage had been achieved. However, willowherb plants that had been sheltered at the time of spray application by strawberry foliage remained healthy. Groundsel by this stage was recovering and growing away from the initial scorching. Plots treated with Shark (both rates) still showed better control of groundsel than the untreated plots. Eight weeks after treatment no differences were observed in terms of weed control with newly germinating willowherb and flowering groundsel found in all plots.

Conclusion

The use of carfentrazone-ethyl formulated as Shark as an over-the-crop dormant season spray appears to have no lasting phytotoxic effects on strawberry plants or on the fruit produced by treated plants at harvest. Both rates of Shark did show promising herbicide efficacy, notably providing good control of American willowherb, and some control of chickweed and groundsel. No residues were detected in fruit sampled at first harvest.

For part two of the trial (post-harvest Shark application), post-harvest applications were made in September 2014 onto a planting of strawberry cv. Elsanta planted as cold stored runners in bags in April 2014. This trial will be assessed for crop safety and effects on yield in spring/summer 2015 and the results reported in the final report for SF 151 due on 31 September 2015. In addition, residue samples will be taken from an additional area where Shark has been applied to larger plots (20 m^2) and will be analysed according to Good Laboratory Practice (GLP) protocols in order to support an EAMU application.

References cited

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

Appendices

Appendix 1: trial plan

Block	Plot	trt
1	1	2
1	2	4
1	3	3
1	4	1

Block	Plot	trt
2	5	1
2	6	2
2	7	4
2	8	3

Block	Plot	trt
3	9	3
3	10	1
3	11	2
3	12	4

Block	Plot	trt
4	13	4
4	14	1
4	15	3
4	16	2

Appendix 2: Crop husbandry records

Date	Product	Rate
16/11/13	Solitaire – propyzamide Stomp – pendimethalin All inter row	3.5 L/ha 3.3 L/ha
17/02/14	Devrinol - napropamide Flexidor - isoxaben All inter row	7 L/ha 2 L/ha
10/03/14	Gusto – 3% metaldehyde	11 kg/ha
18/03/14	Paraat - Dimethomorph	3 kg/ha
03/04/14	Chlorpyrifos Maxicrop – Seaweed extract	1 ml/l 4 ml/L (1000 L water/ha)
07/04/14	Gusto – 3% metaldehyde	11 kg/ha
08/04/14	Fenomenal – fenamidone and fosetyl aluminum Hortiphyte – K_2PO_3	2.25 g/L 4 ml/L (1000 L water/ha)
11/04/14	Harvest – glufosinate ammonium Codacide oil – Vegetable oil Inter row only	12.5 ml/L 12.5 ml/L 180 L/Ha
12/04/14	Rovral - iprodione Thianosan - thiram Hallmark – lambda cyhalothrin Maxicrop – seaweed extract	1 g/L 2 g/L 0.07 g/L 4 ml/L 1000 L water/ha
28/04/14	Fortress – quinoxifen Acaramik – abamectin Apollo – clofentrazine Maxicrop – Seaweed extract	0.25 ml/L 0.5 ml/L 0.4 ml/L 5 ml/L 1000 L water/ha
30/4/14	Fortress – quinoxyfen Systhane – myclobutanil Switch – cyprodinil Maxicrop – seaweed extract	0.25 ml/L 0.45 ml/L 1 g/L 4 ml/L 1000 L water/ha
08/05/14	Systhane – myclobutanil Amistar – azoxystrobin Maxicrop – seaweed extract Borneo – etoxazole Acaramik - dynamec	0.45 ml/L 1 ml/L 4 ml/L 0.35 ml/L 0.5 ml/L 1000 L water/ha
12/05/14	Tiptram – thiram Rovral – iprodione Topas – penconazole Maxicrop – seaweed extract	2 g/L 1 g/L 0.5 ml/L 4 ml/L 1000 L water/ha
08/06/14	Potassium bicarbonate + wetter	100 ml/L 1 ml/L 1000 L water/ha
13/06/14	Topas – penconazole	0.5 ml/L

Date	Product	Rate
	Amistar –azoxystrobin Serenade – *Bacillus subtilis* Sulphur Maxicrop – Seaweed extract Seniphos – $CaPO_3$	1 ml/L 10 ml/L 1.5 ml/L 4 ml/L 5 ml/L 1000 L water/ha
16/06/14	Serenade – *Bacillus subtilis* Sulphur Seniphos – $CaPO_3$ Maxicrop – Seaweed extract SB plant invigorator - Urea	10 ml/l 1.5 ml/L 3 ml/L 4 ml/L 2 ml/L 1000 L water/ha
19/06/14	Potassium bicarbonate + wetter	100 ml/L 1 ml/L 1000 L water/ha
23/06/14	Serenade – *Bacillus subtilis* Sulphur Seniphos – $CaPO_3$ Maxicrop – Seaweed extract SB plant invigorator - Urea	10 ml/l 1.5 ml/L 3 ml/L 4 ml/L 2 ml/L 1000 L water/ha