

SCEPTREPLUS

Final Trial Report

Trial code:	2018. SP01
Title:	AHDB SCEPTREplus carrot herbicide screen
Crop	Group: Field vegetables – Carrot (apiaceae), other umbelliferous root vegetables
Target	General broadleaf weeds and grasses, 3WEEDT EPPO1/99(3) Weeds in root vegetables
Lead researcher:	Angela Huckle
Organisation:	RSK ADAS
Period:	1 st May 2018 – 31 st March 2019
Report date:	29 th November 2019
Report author:	Angela Huckle Emily Lawrence
ORETO Number: (certificate should be attached)	409

I the undersigned, hereby declare that the work was performed according to the procedures herein described and that this report is an accurate and faithful record of the results obtained



14th April 2020
Date

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Authors signature

Trial Summary

Introduction

Linuron has been a key component of herbicide programs for carrots and parsnips along with pendimethalin, prosulfocarb and metribuzin. It formed the basis of commercial programs and was used in a tank mix both pre- and post-emergence, to complement the weed control spectrums of the other actives. With linuron now withdrawn (3rd June 2018), this leaves growers with only pendimethalin and clomazone for pre-emergence weed control for autumn 2018. In addition, the changes to the approval for Defy (prosulfocarb) have also made weed control more difficult with the useful later (up to 3TL) post-emergence applications no longer being permitted. Therefore, it is a high priority for growers to find potential replacement products and understand how they are best included within current programs.

These trials concentrated on potential new herbicides which may partly or fully replace the current use of linuron.

Method

Two separate trials were sited at commercial carrot grower sites on sandy loam soils; one in Norfolk and one in Nottinghamshire. A randomised block design was used, with three replicates of twenty treatments, including two untreated controls and a pre-emergence grower standard for comparison. There were sixty plots in total, each 2m wide by 8m long.

Site 1

Treatments were applied at three timings, either pre-emergence in tank-mix combinations, or in sequence, pre- and post-emergence. Treatments 3 to 12 were applied pre-chit and pre-emergence, while treatments 13 to 20 were applied twice post-emergence—first at two to three true leaves, then again at five to six true leaves (these plots also received a pre-emergence spray of a standard product, Anthem at 3.3 L/ha). Application was with a 2m boom and Oxford Precision Sprayer backpack, at 200 L/ha water volume.

Each plot was assessed for crop safety and treatment efficacy (% weed cover) on six occasions. In addition, plant counts for establishment were made twice, and an assessment to record % root fanging was completed at harvest.

Site 2

Treatments were applied at four timings, either pre-emergence in tank-mix combinations, or in sequence, pre- and post-emergence. Treatments 3 to 12 were applied once to different parts of the plot: pre-chit, pre-emergence to the first six metres; post-chit, pre-emergence to the latter two metres of the plot. Treatments 13 to 20 were applied twice post-emergence—first at two to three true leaves, then again at five to six true leaves (these plots also received a pre-emergence spray of a standard product, Anthem at 3.3 L/ha). Application was with a 2m boom and Oxford Precision Sprayer backpack, at 250 L/ha water volume.

Each plot was assessed for crop phytotoxicity on four occasions, and treatment efficacy (% weed cover) on five occasions. In addition, there was a plant count at the first assessment, and a harvest assessment to record % root fanging.

Results and discussion

Six pre-emergence treatments, and seven post-emergence treatments gave statistically significant weed control ($p < 0.001$) and were crop safe by the final assessment at nine weeks after the final post-emergence application. Weed levels varied between sites, with a high level of 67.6% mean weed cover at Site 1 in the untreated control by the end of the trial assessment period, compared with very low weed levels at Site 2, where there were only an average of 2.67 weeds per 3 quadrats (0.25m² each).

The pre-emergence products Emerger (aclonifen) 1.5 L/ha, Hurricane SC (diflufenican) 0.1 L/ha, Sencorex Flow (metribuzin) 0.15 L/ha, AHDB 9998, AHDB 9918 and AHDB 9917 gave a significant reduction in weed cover for up to 14 weeks after application. They were all applied in a tank-mix with Anthem (pendimethalin) 3.3 L/ha. These treatments gave up to 37% reduction in weed cover. Anthem 3.3 L/ha + Hurricane SC 0.1 L/ha gave the greatest reduction in weed levels out of the pre-emergence

options, reducing weed cover by 77% to a mean of 26.2% across all treated plots by 28th August. AHDB 9998 also performed well as it gives good control of mayweed and groundsel which were key weeds at Site 1, as well as cranesbill, and a little fumitory.

All the post-emergence products, with the exception of Hurricane SC 0.05 L/ha gave a significant reduction in weed cover for up to nine weeks after application. Sencorex Flow, Emerger, or Sencorex Flow in a tank mix with Emerger gave a weed reduction of greater than 70%. Sencorex Flow applied alone at 0.3 L/ha at one to two true leaves, and then again at 0.5 L/ha at four to five true leaves (after a pre-emergence application of Anthem) reduced weed levels to 11.3% and the addition of Emerger gave no significant increase in weed control, but did increase the level of scorch. Therefore, depending on the weed spectrum present it may be safer and more cost-effective to apply each product alone rather than in a tank-mix. Chlorpropham, AHDB 9993 and AHDB 9981 also gave significant weed control, but their efficacy was lower than the best performing products with a percentage weed reduction of 36–44%.

There were no persistent foliar effects from any of the treatments at either site at eight weeks after the final post-emergence application. However, there were some transient crop effects which occurred at one week after the first post-emergence application. The plots affected were those where either post-emergence Emerger, Hurricane SC, AHDB 9981 or Sencorex Flow + Emerger were applied. Emerger gave yellow spotting which persisted for up to two weeks after application, AHDB 9981 gave a slight yellowing in patches on the leaves, and when Sencorex Flow was applied post-emergence in a tank-mix with Emerger this caused scorch and stunting of the crop. At Site 2 only, Hurricane SC caused transient interveinal chlorosis.

There were no significant reductions in plant population at Site 1 for most of the treatments, with the exception of the pre-emergence treatments Anthem + Flexidor 500 0.075 L/ha and Anthem + Sencorex 0.15 L/ha at the assessment at three weeks after the pre-emergence application. In these treatments, plant population was reduced by up to 17%. At this point of assessment most of the crop was at two true leaves. However, significant differences were not seen at the 2nd plant count assessment suggesting that the crop recovered from the treatments, with the exception that there was still a trend for plots treated with Anthem + Flexidor to have a lower plant population. There were no significant reductions or differences in plant population from any of the treatments applied at Site 2.

There were no strong statistical differences in the fanging assessments, and levels were below 5% across all treatments. There was a trend at both sites for slightly higher numbers of fanging where Hurricane SC had been applied at a post-emergence timing, or AHDB 9998 applied at a pre-emergence timing.

Hurricane SC, Emerger, AHDB 9998, AHDB 9918 and AHDB 9917 would be useful additions to carrot growers' weed control programs at pre-emergence and EAMUs have been obtained for Hurricane SC and Emerger. At post-emergence, Sencorex Flow, Emerger, AHDB 9981 and AHDB 9993 would improve weed control at this timing. Sencorex Flow is already approved and was one of the best performing products so could be included in programmes immediately. As post-emergence options are very limited for carrot growers, further authorisations for other products are also needed to prevent reliance on one mode of action and allow growers to control weeds effectively in a long season crop.

It should be noted that three of the authorised products (Emerger, Hurricane and Gamit) contain active ingredients (Aclonifen, diflufenican and clomazone) with similar modes of action from Group F of the herbicides. These are 'bleachers' and act on the inhibition of pigment synthesis. The products have not been tank-mixed in this trial, but it is likely that combining them will increase the bleaching effect and care should be taken.

Table 1. Summary of crop damage and percentage weed cover (back-transformed) (0 to 10; 0 = complete crop death, 10 = no damage). Scores significantly lower than that of the untreated are highlighted in bold. Final post-em site 1; 28th June, final post-em site 2; 4th July. Weeks in brackets are number of weeks after pre-emergence application.

Trt. No.	Mean crop damage (0-10)				Mean weed cover (%)		Mean weed counts in 3 quadrats (0.75m ²)
	Site 1		Site 2		28 th Aug (14 weeks)		29 th Aug (16 weeks)
	17 th July (8 weeks)	28 th Aug (14 weeks)	20 th July (10 weeks)	29 th Aug (16 weeks)	Ang.	Back-trans	
Untreated	10.00	10.0	10.00	10.00	65.0	82.2	2.67
Anthem + Gamit 36 CS	10.00	8.00	8.67	9.94	19.5	11.1	0.33
Anthem + Emerger	9.67	8.33	9.67	9.94	44.7	49.5	0.67
Anthem + Hurricane SC	9.33	8.33	9.00	9.89	25.0	17.8	0.00
Anthem + chlorpropham	9.33	9.00	8.33	9.94	52.1	62.3	0.67
Anthem + Flexidor 500	9.67	8.33	8.00	9.78	43.9	48.1	0.33
Anthem + AHDB 9998	9.67	8.33	5.67	9.89	13.8	5.7	0.33
Anthem + AHDB 9918	9.67	7.67	9.00	9.94	18.3	9.9	0.67
Anthem + Sencorex Flow	9.67	9.00	8.00	9.94	31.9	28.0	0.33
Anthem + AHDB 9999	10.00	8.33	9.00	9.78	37.9	37.7	0.33
Anthem + AHDB 9917	9.67	9.33	8.67	9.89	50.2	59.0	0.67
Anthem, then (Sencorex Flow) x2	9.67	9.33	8.33	10.00	11.9	4.3	1.00
Anthem, then (Emerger) x2	9.33	9.00	7.67	10.00	28.7	23.1	1.00
Anthem, then (Hurricane) x2	9.33	9.00	6.33	9.78	46.3	52.2	0.00
Anthem, then (chlorpropham) x2	9.33	8.00	9.67	9.94	37.6	37.2	0.00
Anthem, then (AHDB 9993) x2	9.33	8.67	9.33	9.72	28.7	23.0	0.33
Anthem, then (AHDB 9981) x2	10.00	9.33	8.33	9.89	37.9	37.8	1.00
Anthem, then (Gamit 36 CS) x2*	*-	*-	9.67	9.94	32.1*	28.3*	0.67
Anthem, then (Emerger + Sencorex Flow) x2	9.00	10.00	7.33	9.94	4.6	0.7	0.67
p value	0.142	0.032	<0.001	0.098	<0.001		<0.001
d.f.	37	37	39	39	39		39
L.S.D.	0.6208	1.252	1.144	0.1654	19.65		0.9172

Conclusion

- At pre-emergence, products Emerger (aclonifen) 1.5 L/ha, Hurricane SC (diflufenican) 0.1 L/ha, Sencorex Flow (metribuzin) 0.15 L/ha, AHDB 9998, AHDB 9918 and AHDB 9917 gave a significant reduction in weed cover for up to 14 weeks after application.
- Anthem + Hurricane SC gave the greatest reduction in weed levels at pre-emergence, reducing weed cover by 77% compared to the untreated control.
- Anthem + Flexidor 0.075 L/ha applied pre-emergence reduced the plant population by 17% at Site 1.
- All the post-emergence products, with the exception of Hurricane SC 0.05 L/ha gave a significant reduction in weed cover for up to nine weeks after application.
- Sencorex Flow, Emerger, or Sencorex Flow in a tank mix with Emerger gave a weed reduction of greater than 70%. Sencorex Flow applied at 0.3 L/ha at one to two true leaves, and then again at 0.5 L/ha at four to five true leaves (after a pre-emergence application of Anthem) reduced weed levels to 11.3% and the addition of Emerger gave no significant increase in weed control, but did increase the level of scorch.
- There were no persistent foliar effects from any of the treatments at eight weeks after the final post-emergence application. However, there were some transient crop effects which occurred at one week after the first post-emergence application. The plots affected were those where either post-emergence Emerger, Hurricane SC, AHDB 9981 or Sencorex Flow + Emerger were applied.

Take home message

Including Emerger or Hurricane SC (both approved under EAMU) at a pre-emergence timing in a tank mix with pendimethalin would improve weed control in carrots. An approval for AHDB 9998, AHDB 9918 or AHDB 9917 would also be useful. At post-emergence, Sencorex Flow gives good weed control and can be included in programs immediately. EAMU authorisations for Emerger, AHDB 9981 or AHDB 9993 for post-emergence use should also be applied for, to give growers a wider range of actives to choose from and reduce the risk of resistance development.

Objective

1. To compare a number of herbicide tank-mixes applied at one of two application timings (pre-emergence or post-emergence) for selectivity (crop safety) and efficacy in carrots, compared with the commercial standard pre-emergence tank-mix (pendimethalin + clomazone).

Trial conduct

UK regulatory guidelines were followed but EPPO guideline took precedence. The following EPPO guidelines were followed:

Relevant EPPO guideline(s)		Variation from EPPO
EPPO PP1/135(4)	Phytotoxicity assessment	None
EPPO PP1/152(4)	Guideline on design and analysis of efficacy evaluation trials	None
EPPO PP1/225 (2)	Minimum effective dose	None
EPPO PP1/181 (4)	Conduct and reporting of efficacy evaluation trials including good experimental practice	None
EPPO PP 1/214(3)	Principles of acceptable efficacy	None
EPPO PP 1/224(2)	Principles of efficacy evaluation for minor uses	None
EPPO PP 1/99(3)	Weeds in root vegetables	Two (see below)

There were two deviations from EPPO guidance:

PP1/99(3) Section 1.4, Design and lay-out of trial:

“Replicates: at least 4”

Study only had 3 replicates – the large number of treatments provides an acceptable number of residual degrees of freedom.

“For seeded crops the whole net plot is harvested”

Only 100 roots were harvested for root quality assessments as yield was not being assessed

Test site

Item	Details	
Location address	Site 1 Field: 33 Alan Bartlett & Sons East Winch, King's Lynn PE32 1NQ Norfolk Grid reference: TF 69003 16395	Site 2 Field: Bridge Field D Skelton & Sons, Bishopfield Farm Serlby, Doncaster DN10 6BA South Yorkshire Grid reference: SK 65073 90069
Crop	Carrot	
Cultivar	Octavo	Nairobi
Soil or substrate type	Freely draining slightly acid sandy soil	
Agronomic practice	See Appendix A	
Prior history of site	See Appendix A	

Trial design

Item	Details
Trial design:	Randomised block
Number of replicates:	3
Row spacing:	80" beds (4 triple lines, 13" row spacing)
Plot size: (w x l)	2m x 8m
Plot size: (m ²)	16m ²
Number of plants per plot:	Approx. 3000
Leaf Wall Area calculations	N/A

Treatment details

AHDB Code	Product name	Active substance	Content of active substance in product (g/L)	Formulation batch number	Formulation type
N/A	Anthem	pendimethalin	400	N/K	Suspension Concentrate
AHDB 9918	N/D	N/D	N/D	N/D	N/D
N/A	Gamit 36 CS	clomazone	360	N/K	Capsule Suspension
N/A	Sencorex Flow	metribuzin	600	EM4H002443	Suspension Concentrate
AHDB 9998	N/D	N/D	N/D	N/D	N/D
N/A	Hurricane SC	diflufenican	500	15068154	Suspension Concentrate
N/A	Flexidor 500	isoxaben	500	F006H41002	Suspension Concentrate
N/A	Intruder	chlorpropham	400	334H	Emulsifiable Concentrate
was AHDB 9994	Emerger	aclonifen	600	EV56006446	Suspension Concentrate
AHDB 9981	N/D	N/D	N/D	N/D	N/D
AHDB 9999	N/D	N/D	N/D	N/D	N/D
AHDB 9993	N/D	N/D	N/D	N/D	N/D
AHDB 9917	N/D	N/D	N/D	N/D	N/D

Application schedule

Treatment number	Treatment: product name or AHDB code	Application timing code	Rate of active substance (g/ha)	Rate of product (L/ha)
1	Untreated	-	-	-
2	Untreated	-	-	-
3*	Anthem + Gamit 36 CS	A, B	1320 72	3.3 0.2
4	Anthem + Emerger	A, B	1320 900	3.3 1.5
5	Anthem + Hurricane SC	A, B	1320 50	3.3 0.1
6	Anthem + Intruder	A, B	1320 1120	3.3 2.8
7	Anthem + Flexidor 500	A, B	1320 37.5	3.3 0.075
8	Anthem + AHDB 9998	A, B	1320 1344	3.3 1.4
9	Anthem + AHDB 9918	A, B	1320 240	3.3 0.48
10	Anthem + Sencorex Flow	A, B	1320 90	3.3 0.15
11	Anthem + AHDB 9999	A, B	1320 1600	3.3 2.0
12	Anthem + AHDB 9917	A, B	1320 525	3.3 0.7
13	Anthem	A	1320	3.3

Treatment number	Treatment: product name or AHDB code	Application timing code	Rate of active substance (g/ha)	Rate of product (L/ha)
	Sencorex Flow	C	180	0.3
	Sencorex Flow	D	300	0.5
14	Anthem	A	1320	3.3
	Emerger	C	300	0.5
	Emerger	D	300	0.5
15	Anthem	A	1320	3.3
	Hurricane	C	25	0.05
	Hurricane	D	25	0.05
16	Anthem	A	1320	3.3
	Intruder	C	720	1.8
	Intruder	D	720	1.8
17	Anthem	A	1320	3.3
	AHDB 9993	C	160	1.0
	AHDB 9993	D	320	2.0
18	Anthem	A	1320	3.3
	AHDB 9981	C	112.5	(kg/ha) 0.25
	AHDB 9981	D	112.5	(kg/ha) 0.25
19	Anthem	A	1320	3.3
	Gamit 36 CS	C	18	0.05
	Gamit 36 CS	D	360	**1.0
20	Anthem	A	1320	3.3
	Emerger +	C	900	0.5
	Sencorex Flow		180	0.3
	Emerger +	D	900	0.5
	Sencorex Flow		180	0.3

* Grower standard

** Applied at 10x rate at the East site

Application details

Site 1

	Timing A	Timing B	Timing C	Timing D
Application date	25/05/2018	Not applied*	15/06/2018	28/06/2018
Time of day	10:00 – 12:00		13:15 – 13:50	12:46 – 13:30
Crop growth stage (Max, min average BBCH)	00-03		12-13	15-16
Crop height (cm)	N/A		5	20
Crop coverage (%)	N/A		17	50
Application Method	spray		spray	spray
Application Placement	soil		foliar	foliar
Application equipment	Oxford Precision Sprayer (knapsack)		Oxford Precision Sprayer (knapsack)	Oxford Precision Sprayer (knapsack)
Nozzle pressure	2.4 bar		2.4 bar	2.4 bar
Nozzle type	Flat fan		Flat fan	Flat fan
Nozzle size	02F110		02F110	02F110
Application water volume/ha	200		200	200
Temperature of air – shade (°C)	16.2 – 18.5		22.5 – 22.7	24.6 – 26.0
Relative humidity (%)	88.2 – 93.4		50.1 – 51.3	61.3 – 62.3
Wind speed range (mph)	1.7 – 3.5		1.9 – 4.8	2.3
Dew presence (Y/N)	N/A		N	N
Temperature of soil – 10cm (°C)	15.0	20.0	23.0	
Wetness of soil – 2-5 cm	Damp	Dry	Dry	
Cloud cover (%)	100	40	0	

* Crop grew too fast to apply treatment in time, but this spray was not integral to the trial – more for grower knowledge exchange.

Site 2

	Timing A	Timing B	Timing C	Timing D
Application date	12/05/2018	19/05/2018	12/06/2018	04/07/2018
Time of day	13:30 – 15:00	14:40 – 15:40	12:30 – 14:00	
Crop growth stage (Max, min average BBCH)	pre-em, pre-chit (00-03)	pre-em, post-chit (03-07)	2-3 true leaves (12-13)	5-6 true leaves (15-16)
Crop height (cm)	N/A	N/A	15	25
Crop coverage (%)	N/A	N/A	35	65
Application Method	spray	spray	spray	spray
Application Placement	soil	soil	foliar	foliar
Application equipment	Oxford Precision Sprayer (knapsack)			
Nozzle pressure	2.0 bar	2.0 bar	2.0 bar	2.0 bar
Nozzle type	Flat fan	Flat fan	Flat fan	Flat fan
Nozzle size	03F110	03F110	03F110	03F110
Application water volume/ha	250	250	250	250
Temperature of air – shade (°C)	18.5 – 23.0	25.3 – 26.6	17.5 – 17.9	22.2 – 23.0
Relative humidity (%)	53.5 – 59.5	42.3 – 49.9	54.5 – 64.6	45.0 – 45.5

Wind speed range (mph)	1.4 – 2.8	0.9 – 1.8	3.7 – 3.8	2.0 – 2.3
Dew presence (Y/N)	N	N	N	N
Temperature of soil – 10cm (°C)	18.8	20.6	19.8	30.8
Wetness of soil – 2-5 cm	Damp	Damp	Dry	Dry
Cloud cover (%)	95	5	90	20

Untreated levels of pests/pathogens at application and through the assessment period

Site 1

Common name	Scientific Name	EPPO Code	Infection level at start of assessment period (3 weeks)	Infection level mid-assessment period (7 weeks)	Infection level at end of assessment period (13 weeks)
Broad leaved weeds and grasses	N/A	3WEEDT	25.17% (untreated average)	80.8% (untreated average)	83.3% (untreated average)

Site 2

Common name	Scientific Name	EPPO Code	Infection level at start of assessment period (4 weeks)	Infection level mid-assessment period (8 weeks)	Infection level at end of assessment period (16 weeks)
Broad leaved weeds and grasses	N/A	3WEEDT	14.24 per m ² (untreated average)	8.85 per m ² (untreated average)	14.24 per m ² (untreated average)

Assessment details

Site 1

Evaluation date	Evaluation Timing (DA)*	Crop Growth Stage (BBCH)	Evaluation type (efficacy, phytotox)	What was assessed and how
15/06/2018	22	12-13	Efficacy, Phytotox, Plant count	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover as whole plot score; weed species present, plant counts over 1m – single row.
21/06/2018	28	14	Efficacy, Phytotox	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover as whole plot score; weed species present
28/06/2018	35	15	Efficacy, Phytotox, Plant count	Phytotox (scale 0-10, 0 = Dead)

				Percentage of weed cover as whole plot score; weed species present, plant counts over 1m – single row.
17/07/2018	54	16-17	Efficacy, Phytotox	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover as whole plot score; comments on crop effects
30/07/2018	67	18	Efficacy, Phytotox	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover as whole plot score; comments on crop effects
28/08/2018	96	48	Efficacy, Phytotox	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover as whole plot score; comments on crop effects
25/09/2018	124	49	Harvest	Roots – % fanged

* DA – days after application

Site 2

Evaluation date	Evaluation Timing (DA)*	Crop Growth Stage (BBCH)	Evaluation type (efficacy, phytotox)	What was assessed and how
08/06/2018	28	12	Efficacy, Phytotox, Plant count	Phytotox (scale 0-10, 0 = Dead) Counts of weed species Plant counts over 1m – single row
18/06/2018	38	13	Phytotox Plant count	Phytotox (scale 0-10, 0 = Dead) Plant counts over 1m – single row
04/07/2018	54	15-16	Efficacy	Counts of weed species
20/07/2018	70	42-45	Efficacy, Phytotox,	Phytotox (scale 0-10, 0 = Dead) Counts of weed species
13/08/2018	94	49	Efficacy, Phytotox	Phytotox (scale 0-10, 0 = Dead) Counts of weed species
29/08/2018	110	49	Efficacy, Phytotox	Phytotox (scale 0-10, 0 = Dead) Counts of weed species
09/10/2018	141	49	Harvest	Roots – % fanged

* DA – days after application

Statistical analysis

The trial design was a randomised block design with three replicates of twenty treatments, including two untreated controls and a grower standard. Split plots were included at Site 2 only, and only for the pre-emergence applications (treatments 3-13) to investigate the effect of application of the residual herbicides before (Timing A) and after (Timing B) the seed had chit. Only the data from the plot area treated at Timing A was analysed. Timing B was only demonstrated on grower open days, and brief comments noted.

As the distribution of weeds was uneven across the trial – which is not unexpected in field situations – there was a need to transform these variables prior to analysis. An angular transformation was used.

All data were analysed by ANOVA using Genstat 18.4 by Chris Dyer and Emily Lawrence at RSK ADAS. For the % efficacy data, calculated by Abbotts formula, an angular transformation was carried out and then back transformed means presented, from which Abbotts formula was used to calculate the % reduction in weeds, with the exception of site 2 where the weed levels were too low.

Results

Phytotoxicity

The results of phytotoxicity assessments from six dates are presented in Table 2 and Figure 1. These were scored on a scale from 0 to 10, with 0 being 'dead', and 10 being 'no effect'. Plots scored 8 or above were deemed to have a commercially acceptable level of damage.

Phytotoxicity was recorded using the following scale:

Crop tolerance score	Equivalent to crop damage (% phytotoxicity)
0	complete crop kill 100%
1	80-95% damage
2	70-80%
3	60-70%
4	50-60%
5	40-50%
6	25-40%
7	15-25%
8*	10-15%
9	5-10%
10	no damage

* 8 = acceptable damage, i.e. damage unlikely to reduce yield, and acceptable to the farmer.

There were no persistent foliar effects from any of the treatments at either site at eight weeks after the final post-emergence application. However, there were some transient crop effects which occurred at one week after the first post-emergence application. The plots affected were those where either post-emergence Emerger (aclonifen), AHDB 9981, Hurricane (diflufenican) or Sencorex Flow (metribuzin) + Emerger were applied. Emerger gave yellow spotting which persisted for up to two weeks after application, AHDB 9981 gave a slight yellowing in patches on the leaves, and when Sencorex Flow was applied post-emergence in a tank-mix with Emerger this caused scorch and stunting of the crop. At Site 2 only, Hurricane caused transient interveinal chlorosis.

In the pre-emergence treatments, a moderate effect on the crop was seen in one treatment only. This was at Site 2 in plots treated with pendimethalin + AHDB 9998, and was exhibited as the appearance of a reduced plant stand, but in the plant population section there was no significant reduction in seedling counts. In addition, a score of below eight was seen at the 30th July assessment at Site 1 in the plots where Emerger or chlorpropham was applied as a tank mix with pendimethalin. However, this was not an effect from the treatments, as there were higher weed levels in these plots which would have stunted crop growth, and was recorded as a crop effect by the assessor.

Table 2. Mean phytotoxicity scores from Site 1 at six dates throughout the trial period (0 to 10; 0 = complete crop death, 10 = no damage). The final post-emergence application was applied on 28th June. Scores significantly lower than that of the untreated are highlighted in bold.

Treatment	Mean crop damage scores (0-10)					
	15 th June (3 weeks)	21 st June (4 weeks)	28 th June (5 weeks)	17 th July (8 weeks)	30 th July (10 weeks)	28 th Aug (14 weeks)
Untreated	10.00	10.00	10.00	10.00	10.00	10.0
Anthem + Gamit 36 CS	10.00	9.33	9.33	10.00	8.67	8.00
Anthem + Emerger	10.00	10.00	10.00	9.67	7.67	8.33
Anthem + Hurricane SC	9.33	10.00	10.00	9.33	9.67	8.33
Anthem + chlorpropham	10.00	10.00	10.00	9.33	7.33	9.00
Anthem + Flexidor 500	10.00	10.00	10.00	9.67	8.67	8.33
Anthem + AHDB 9998	10.00	9.33	9.33	9.67	10.00	8.33
Anthem + AHDB 9918	10.00	9.33	9.33	9.67	8.33	7.67
Anthem + Sencorex Flow	9.67	10.00	10.00	9.67	8.00	9.00
Anthem + AHDB 9999	9.00	9.00	9.00	10.00	8.33	8.33
Anthem + AHDB 9917	9.67	9.67	9.67	9.67	9.00	9.33
Anthem, then (Sencorex Flow) x2	10.00	8.67	9.33	9.67	10.00	9.33
Anthem, then (Emerger) x2	10.00	6.33	8.00	9.33	8.33	9.00
Anthem, then (Hurricane) x2	9.67	8.33	8.33	9.33	8.67	9.00
Anthem, then (chlorpropham) x2	10.00	10.00	10.00	9.33	9.33	8.00
Anthem, then (AHDB 9993) x2	9.67	10.00	10.00	9.33	7.67	8.67
Anthem, then (AHDB 9981) x2	10.00	6.67	7.33	10.00	10.00	9.33
Anthem, then (Gamit 36 CS) x2*	10.00	10.00	10.00	*-	*-	*-
Anthem, then (Emerger + Sencorex Flow) x2	10.00	5.67	8.00	9.00	10.00	10.00
p value	0.047	<0.001	<0.001	0.142	<0.001	0.032
d.f.	39	39	39	37	37	37
L.S.D.	0.5087	1.233	1.0603	0.6208	1.216	1.252

(-) post-emergence treatment

* No data as this treatment was applied at the wrong rate.

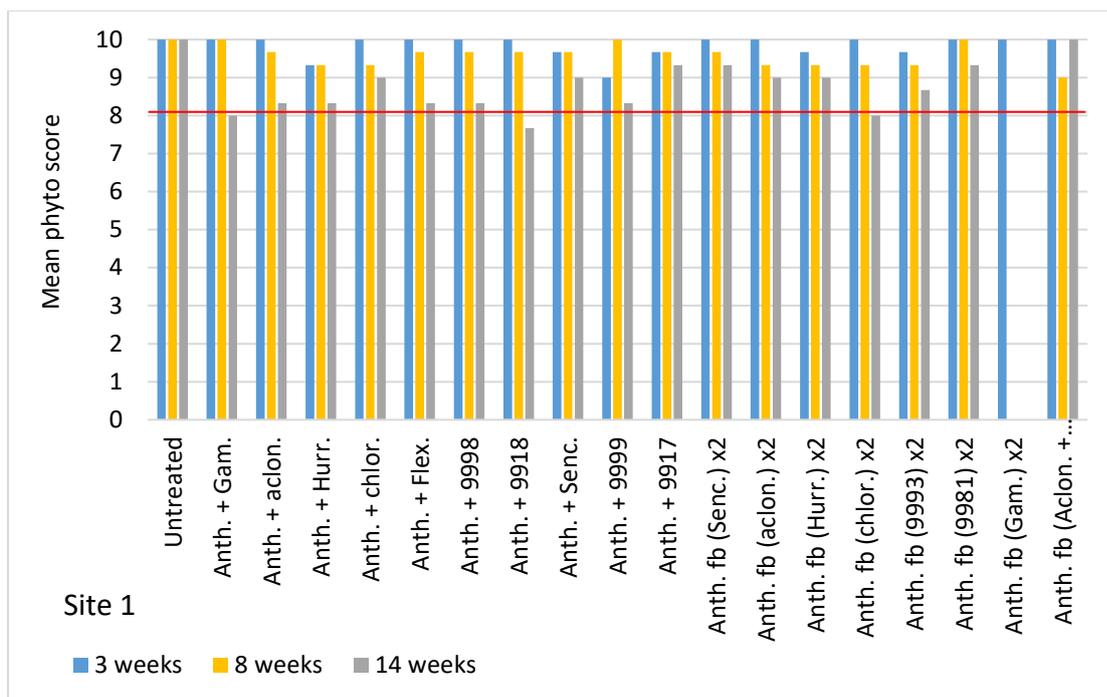


Figure 1. Mean phytotoxycity scores at three, eight and fourteen weeks after Timing A treatment application. Scores of 8 or above deemed acceptable damage (as indicated by red line).

Table 3. Mean phytotoxycity scores from Site 2 at three dates throughout the trial period (0 to 10; 0 = complete crop death, 10 = no damage). Scores significantly lower than that of the untreated are highlighted in bold. The final post-emergence application was applied on 4th July. Scores significantly lower than that of the untreated are highlighted in bold.

Treatment	Mean crop damage scores (0-10)		
	18 th June (6 weeks)	20 th July (10 weeks)	29 th Aug (16 weeks)
Untreated	10.00	10.00	10.00
Anthem + Gamit 36 CS	10.00	8.67	9.94
Anthem + Emerger	10.00	9.67	9.94
Anthem + Hurricane SC	10.00	9.00	9.89
Anthem + chlorpropham	10.00	8.33	9.94
Anthem + Flexidor 500	10.00	8.00	9.78
Anthem + AHDB 9998	10.00	5.67	9.89
Anthem + AHDB 9918	10.00	9.00	9.94
Anthem + Sencorex Flow	10.00	8.00	9.94
Anthem + AHDB 9999	10.00	9.00	9.78
Anthem + AHDB 9917	10.00	8.67	9.89

Treatment	Mean crop damage scores (0-10)		
	18 th June (6 weeks)	20 th July (10 weeks)	29 th Aug (16 weeks)
Anthem, then (Sencorex Flow) x2	9.67	8.33	10.00
Anthem, then (Emerger) x2	9.00	7.67	10.00
Anthem, then (Hurricane) x2	9.00	6.33	9.78
Anthem, then (chlorpropham) x2	10.00	9.67	9.94
Anthem, then (AHDB 9993) x2	9.67	9.33	9.72
Anthem, then (AHDB 9981) x2	10.00	8.33	9.89
Anthem, then (Gamit 36 CS) x2	9.33	9.67	9.94
Anthem, then (Emerger + Sencorex Flow) x2	9.33	7.33	9.94
p value	<0.001	<0.001	0.098
d.f.	39	39	39
L.S.D.	0.3740	1.144	0.1654

() post-emergence treatment

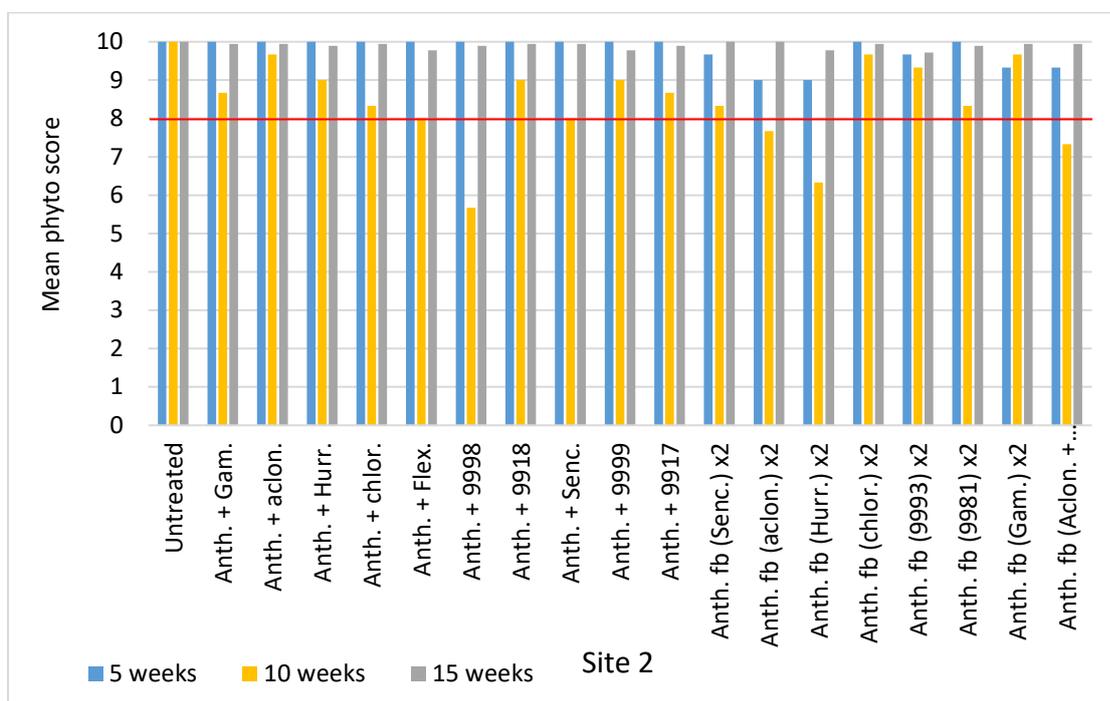


Figure 2. Mean phytotoxicity scores at five, ten and fifteen weeks after Timing A treatment application. Scores of 8 or above deemed acceptable damage (as indicated by red line).

Plant population

There were no significant reductions in plant population at Site 1 for most of the treatments, with the exception of the pre-emergence treatments Anthem + Flexidor 500 and Anthem + Sencorex at the assessment at three weeks after the pre-emergence application (Table 4). In these treatments, plant population was reduced by up to 17%. At this point of assessment most of the crop was at two true

leaves. However, significant differences were not seen at the 2nd plant count assessment suggesting that the crop recovered from the treatments, with the exception that there was still a trend for plots treated with Anthem + Flexidor to have a lower plant population. There were no significant reductions or differences in plant population from any of the treatments applied at Site 2.

Table 4. Plant population at both sites, at two dates; first assessment before the first post-emergence application, and the second after the final the post-emergence application. Numbers in **bold** are significantly different to the untreated control, and numbers in *italics* are where only the pre-emergence treatments would have affected the plots.

Treatment	Plant population counts (plants/m/single row)			
	Counts are from a single row of the central triple row			
	Site 1		Site 2	
	15 th June (3 weeks)	28 th June (5 weeks)	8 th June (4 weeks)	18 th June (6 weeks)
Untreated	23.3	16.7	19	19
Anthem + Gamit 36 CS	23.2	17.7	19	19
Anthem + Emerger	23.7	16.3	23	23
Anthem + Hurricane SC	22.5	16.9	19	19
Anthem + chlorpropham	23.1	16.3	20	20
Anthem + Flexidor 500	19.1	13.6	19	19
Anthem + AHDB 9998	21.3	16.1	19	19
Anthem + AHDB 9918	21.4	17.8	23	23
Anthem + Sencorex Flow	19.4	15.7	19	19
Anthem + AHDB 9999	22.0	15.7	20	20
Anthem + AHDB 9917	20.5	14.0	20	20
Anthem, then (Sencorex Flow) x2	24.7	16.0	26	26
Anthem, then (Emerger) x2	22.8	18.4	20	20
Anthem, then (Hurricane) x2	23.9	18.1	21	21
Anthem, then (chlorpropham) x2	20.9	17.8	19	19
Anthem, then (AHDB 9993) x2	19.2	15.6	23	23
Anthem, then (AHDB 9981) x2	22.8	15.4	19	19
Anthem, then (Gamit 36 CS) x2*	24.6	17.7	20	20
Anthem, then (Emerger + Sencorex Flow) x2	23.7	18.1	22	21

Treatment	Plant population counts (plants/m/single row) Counts are from a single row of the central triple row			
	Site 1		Site 2	
	15 th June (3 weeks)	28 th June (5 weeks)	8 th June (4 weeks)	18 th June (6 weeks)
p value	0.032	NS	NS	NS
d.f.	39	39	39	39
L.S.D.	3.462	3.140	5.9	5.871

() post-emergence treatment

Weed control

The results for the mean percentage weed cover per treatment for Site 1 are presented in Table 5 and Figure 3. The percent reduction in weed cover compared to the untreated control was calculated from these figures (using Abbotts formula), and results for each treatment are listed in Table 7. For Site 2, the data is presented as weed counts per plot as the levels were very low (Table 6). Given these low levels, we were unable to carry out an angular transformation and the data is presented as a standard ANOVA.

At Site 1, six pre-emergence treatments and seven post-emergence treatments gave a significant reduction in overall weed cover (%) at the final assessment. The pre-emergence products Emerger, Hurricane SC, Sencorex Flow, AHDB 9998, AHDB 9918 and AHDB 9917 in a tank-mix with the standard Anthem gave a significant reduction in weed cover up to 14 weeks after application. On the weed spectrum present (cranesbill, mayweed, groundsel and a little fumitory), Anthem + Hurricane SC gave the best weed control from the pre-emergence options, reducing weed levels by 77% to a mean of 26.2% across all treated plots by 28th August.

All the post-emergence products, with the exception of Hurricane SC gave a significant reduction in weed cover for up to nine weeks after application, with Sencorex Flow, Emerger, or Sencorex Flow in a tank mix with Emerger giving a weed reduction of greater than 70%. Sencorex Flow applied alone at two timings after a pre-emergence application of Anthem reduced weed levels to 11.3%, and the addition of Emerger gave no significant increase in weed control, but did increase the level of scorch.

At Site 2, weed levels were too low to be able to carry out a statistical analysis using transformations, therefore only a simple ANOVA is presented. Although there were some significant differences at the final two assessments, weed levels were too low to be conclusive in this trial.

Table 5. Mean percentage weed cover values (back-transformed) for Site 1 at four, five, eight, ten and fourteen weeks after Timing A treatment application. Weed levels significantly different than that of the untreated are highlighted in **bold**.

Trt. No.	Mean weed cover (%)									
	21 st June (4 weeks)		28 th June (5 weeks)		17 th July (8 weeks)		30 th July (10 weeks)		28 th Aug (14 weeks)	
	Ang.	Back-trans	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans
Untreated	29.0	23.9	54.9	67.0	65.0	82.2	72.1	91.1	67.6	85.5
Anthem + Gamit 36 CS	9.9	2.9	19.9	11.6	19.5	11.1	25.3	18.3	47.9	55.1
Anthem + Emerger	23.4	15.8	37.2	36.5	44.7	49.5	53.4	64.4	46.8	53.1
Anthem + Hurricane SC	10.5	3.3	17.7	9.3	25.0	17.8	28.3	22.4	26.2	19.6
Anthem + chlorpropham	24.1	16.6	50.2	59.0	52.1	62.3	62.3	78.4	53.1	63.9

Trt. No.	Mean weed cover (%)									
	21 st June (4 weeks)		28 th June (5 weeks)		17 th July (8 weeks)		30 th July (10 weeks)		28 th Aug (14 weeks)	
	Ang.	Back-trans	Ang.	Back-trans	Ang.	Back-trans	Ang.	Back-trans	Ang.	Back-trans
Anthem + Flexidor 500	20.5	12.2	37.8	37.6	43.9	48.1	55.8	68.4	52.7	63.3
Anthem + AHDB 9998	7.3	1.6	12.2	4.5	13.8	5.7	23.6	16.1	29.5	24.3
Anthem + AHDB 9918	10.9	3.6	16.6	8.2	18.3	9.9	25.3	18.3	38.2	38.2
Anthem + Sencorex Flow	17.8	9.4	29.3	24.0	31.9	28.0	36.8	35.8	43.8	48.0
Anthem + AHDB 9999	9.3	2.6	18.4	10.0	37.9	37.7	40.2	41.6	50.0	58.7
Anthem + AHDB 9917	24.8	17.6	42.2	45.2	50.2	59.0	53.7	64.9	43.2	46.9
Anthem, then (Sencorex Flow) x2	8.1	2.0	11.0	3.6	11.9	4.3	16.6	8.2	11.3	3.9
Anthem, then (Emerger) x2	18.1	9.6	31.5	27.2	28.7	23.1	31.8	27.7	30.3	25.4
Anthem, then (Hurricane) x2	20.7	12.5	43.1	46.7	46.3	52.2	54.3	66.0	52.6	63.1
Anthem, then (chlorpropham) x2	17.1	8.6	42.3	45.3	37.6	37.2	49.2	57.3	47.5	54.4
Anthem, then (AHDB 9993) x2	12.7	4.8	21.1	13.0	28.7	23.0	37.9	37.7	43.7	47.7
Anthem, then (AHDB 9981) x2	14.6	6.4	28.2	22.4	37.9	37.8	54.9	67.0	45.9	51.5
Anthem, then (Gamit 36 CS) x2*	17.1	8.6	27.5	21.4	32.1 *	28.3*	38.0 *	37.9*	14.8 *	6.5*
Anthem, then (Emerger + Sencorex Flow) x2	3.8	0.5	6.5	1.3	4.6	0.7	11.7	4.1	5.4	0.9
p value	<0.001		<0.001		<0.001		<0.001		<0.001	
d.f.	39		29		39		38		39	
L.S.D.	6.90		18.74		13.36		15.67		19.65	

() post-emergence treatment

* Applied at 10x label rate

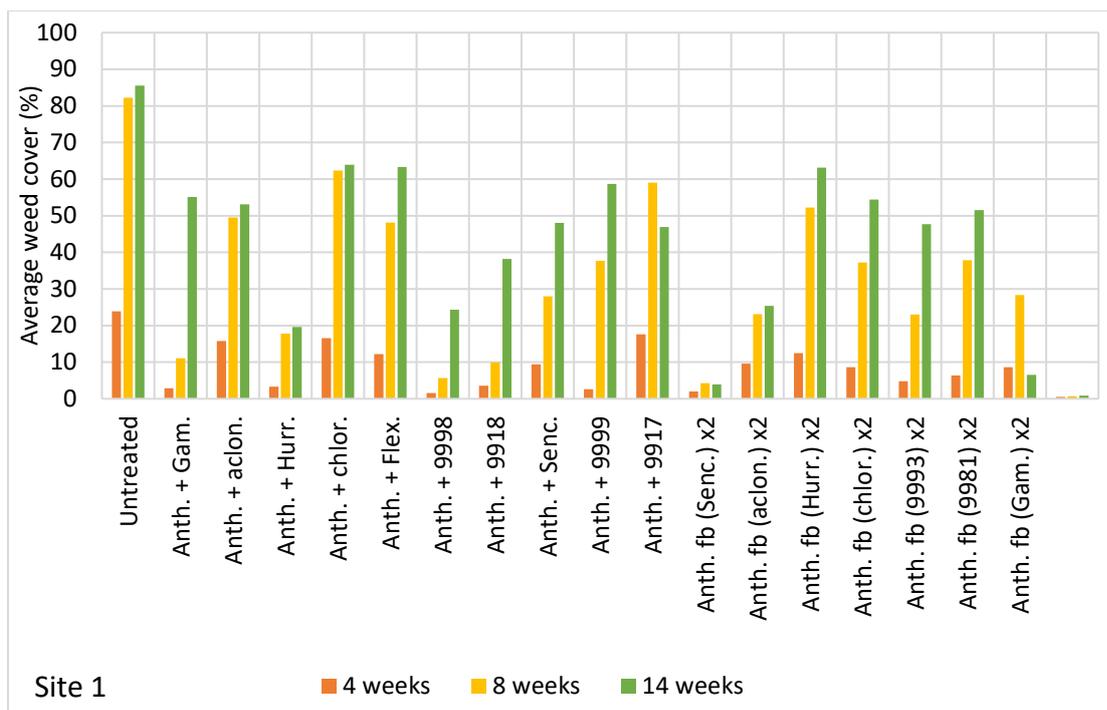


Figure 3. Mean weed cover (%) at four, eight and fourteen weeks after Timing A treatment application (back-transformed values).

Table 6. Mean of the number of weeds per treatment present in three quadrats from five assessment dates; 4, 8, 10, 13 and 16 weeks after Application A (Site 2). Weed levels significantly different than that of the untreated are highlighted in **bold**.

Treatment	Mean count in three quadrats (quadrat 0.25m ²)				
	8 th June (4 weeks)	4 th July (8 weeks)	20 th July (10 weeks)	13 th Aug (13 weeks)	29 th Aug (16 weeks)
Untreated	2.67	1.67	2.67	1.83	2.67
Anthem + Gamit 36 CS	1.00	1.00	1.33	0.67	0.33
Anthem + Emerger	1.33	1.33	2.00	1.00	0.67
Anthem + Hurricane SC	1.33	0.33	0.33	0.33	0.00
Anthem + chlorpropham	0.67	2.00	0.67	0.67	0.67
Anthem + Flexidor 500	1.67	1.33	1.00	0.67	0.33
Anthem + AHDB 9998	0.67	0.33	1.00	0.33	0.33
Anthem + AHDB 9918	0.67	0.67	1.33	0.67	0.67
Anthem + Sencorex Flow	2.00	2.00	1.33	2.00	0.33
Anthem + AHDB 9999	1.33	2.00	1.00	1.00	0.33
Anthem + AHDB 9917	1.00	1.00	1.00	1.00	0.67

Anthem, then (Sencorex Flow) x2	1.33	1.00	1.67	1.67	1.00
Anthem, then (Emerger) x2	1.33	1.33	1.67	1.00	1.00
Anthem, then (Hurricane) x2	1.33	1.00	0.67	0.00	0.00
Anthem, then (chlorpropham) x2	2.33	1.33	0.33	0.00	0.00
Anthem, then (AHDB 9993) x2	1.67	1.00	0.67	0.33	0.33
Anthem, then (AHDB 9981) x2	2.00	0.33	1.00	1.33	1.00
Anthem, then (Gamit 36 CS) x2	1.33	2.00	1.33	0.67	0.67
Anthem, then (Emerger + Sencorex Flow) x2	1.33	1.00	1.67	1.33	0.67
p value	NS	NS	NS	<0.001	<0.001
d.f.	39	39	39	39	39
L.S.D.	2.358	1.964	1.889	1.1206	0.9172

() post-emergence treatment

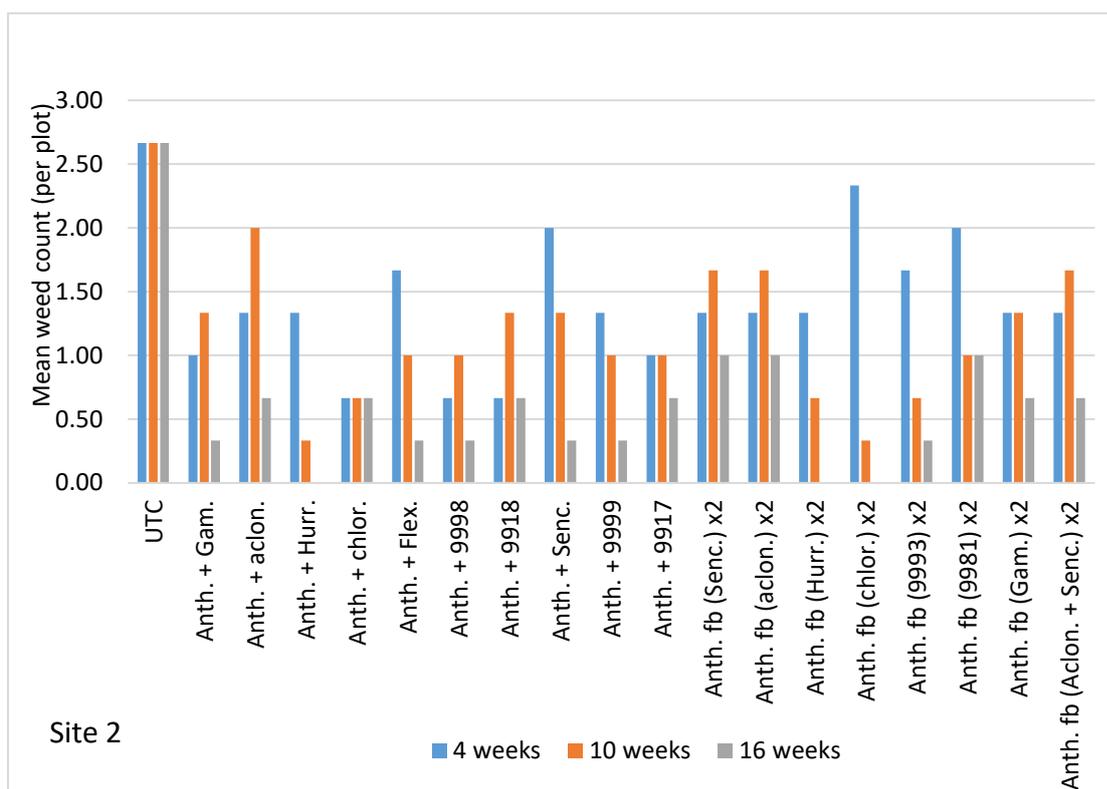


Figure 4. Mean weed count (per plot) at four, ten and sixteen weeks after Timing A treatment application.

Weed control - % weed reduction – Abbotts formula

Table 7. Percentage reduction in weed cover at Site 1 at three, four, five, eight, ten and fourteen weeks after Timing A treatment application (calculated using Abbotts formula).

Treatment	Weed cover reduction (%)					
	15 th June (3 weeks)	21 st June (4 weeks)	28 th June (5 weeks)	17 th July (8 weeks)	30 th July (10 weeks)	28 th Aug (14 weeks)
Anthem + Gamit 36 CS	37.93	87.87	82.69	86.50	79.91	35.56
Anthem + Emerger	51.23	33.89	45.52	39.78	29.31	37.89
Anthem + Hurricane SC	44.33	86.19	86.12	78.35	75.41	77.08
Anthem + chlorpropham	35.96	30.54	11.94	24.21	13.94	25.26
Anthem + Flexidor 500	2.46	48.95	43.88	41.48	24.92	25.96
Anthem + AHDB 9998	52.71	93.31	93.28	93.07	82.33	71.58
Anthem + AHDB 9918	50.25	84.94	87.76	87.96	79.91	55.32
Anthem + Sencorex Flow	47.78	60.67	64.18	65.94	60.70	43.86
Anthem + AHDB 9999	29.06	89.12	85.07	54.14	54.34	31.35
Anthem + AHDB 9917	44.33	26.36	32.54	28.22	28.76	45.15
Anthem, then (Sencorex Flow) x2	31.53	91.63	94.63	94.77	91.00	95.44
Anthem, then (Emerger) x2	28.08	59.83	59.40	71.90	69.59	70.29
Anthem, then (Hurricane) x2	15.27	47.70	30.30	36.50	27.55	26.20
Anthem, then (chlorpropham) x2	28.08	64.02	32.39	54.74	37.10	36.37
Anthem, then (AHDB 9993) x2	28.08	79.92	80.60	72.02	58.62	44.21
Anthem, then (AHDB 9981) x2	19.70	73.22	66.57	54.01	26.45	39.77
Anthem, then (Gamit 36 CS) x2*	28.08	64.02	68.06	65.57*	58.40*	92.40*
Anthem, then (Emerger + Sencorex Flow) x2	35.96	97.91	98.06	99.15	95.50	98.95

() post-emergence treatment

* Applied at 10x label rate

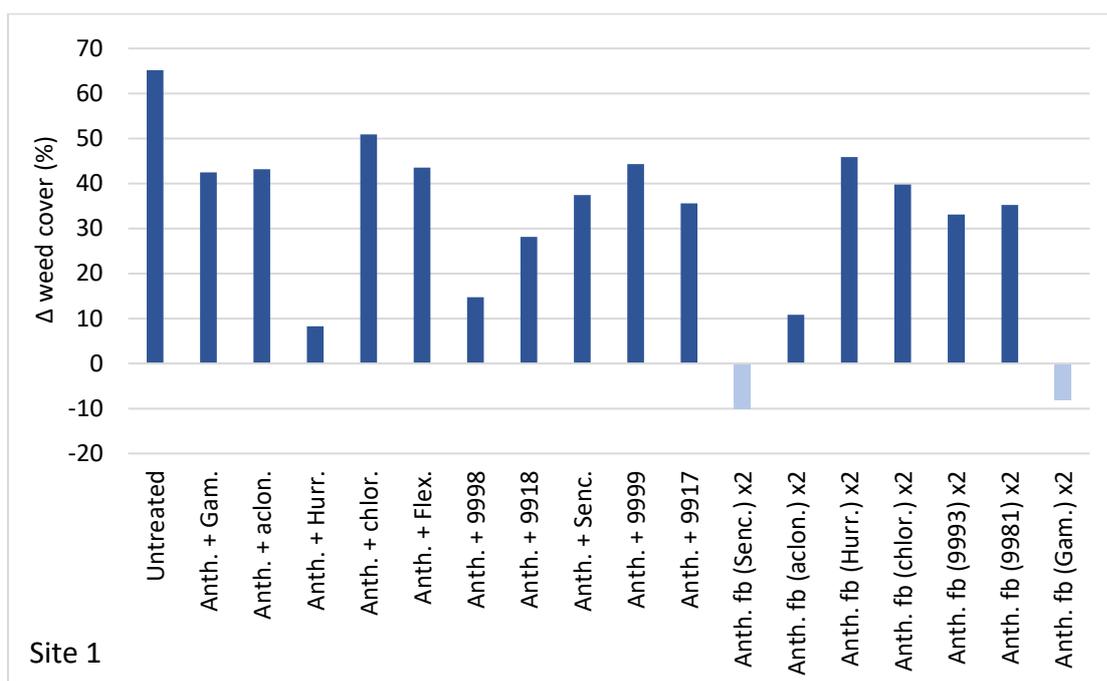


Figure 5. Percentage change in weed cover at Site 1 over the fourteen week assessment period (+ve change = weed cover increase; -ve change = weed cover decrease).

Fanging of roots

Fanging of the carrots was assessed from a subsample of 100 roots dug from each plot at both sites. Results are presented in Table 8 below. There were no strong statistical differences in the fanging assessments, and levels were below 5% across all treatments. There was a trend at both sites for slightly higher numbers of fanging where Hurricane SC had been applied at a post-emergence timing, or AHDB 9998 applied at a pre-emergence timing.

Table 8. Percentage of roots with fanging -

Treatment	Roots with fanging (%)	
	Site 1	Site 2
	25 th September	9 th October
Untreated	2.34	2.15
Anthem + Gamit 36 CS	2.00	3.00
Anthem + Emerger	3.33	4.00
Anthem + Hurricane SC	2.33	2.00
Anthem + chlorpropham	2.50	2.67
Anthem + Flexidor 500	2.00	4.00
Anthem + AHDB 9998	5.33	4.00
Anthem + AHDB 9918	2.00	2.67
Anthem + Sencorex Flow	2.67	1.33

Treatment	Roots with fanging (%)	
	Site 1	Site 2
	25 th September	9 th October
Anthem + AHDB 9999	3.00	3.00
Anthem + AHDB 9917	0.67	2.00
Anthem, then (Sencorex Flow) x2	1.00	2.67
Anthem, then (Emerger) x2	1.00	3.33
Anthem, then (Hurricane) x2	4.67	4.67
Anthem, then (chlorpropham) x2	1.00	2.67
Anthem, then (AHDB 9993) x2	1.00	3.00
Anthem, then (AHDB 9981) x2	1.67	1.67
Anthem, then (Gamit 36 CS) x2*	2.50	2.67
Anthem, then (Emerger + Sencorex Flow) x2	2.33	2.67
p value	0.053	NS
d.f.	36	39
L.S.D.	2.59	2.899

Discussion

Six pre-emergence treatments, and seven post-emergence treatments gave statistically significant weed control ($p < 0.001$) and were crop safe by the final assessment at nine weeks after the final post-emergence application. Weed levels varied between sites, with a notably high mean weed cover level of 67.6% at Site 1 in the untreated control by the end of the trial assessment period, compared with very low weed levels at Site 2, where there were only 2.67 weeds per three quadrats (each 0.25m²).

The pre-emergence products Emerger (aclonifen) 1.5 L/ha, Hurricane SC (diflufenican) 0.1 L/ha, Sencorex Flow (metribuzin) 0.15 L/ha, AHDB 9998, AHDB 9918 and AHDB 9917 gave a significant reduction in weed cover for up to 14 weeks after application. They were all applied in a tank-mix with Anthem (pendimethalin) 3.3 L/ha. These treatments gave up to 37% reduction in weed cover. Anthem + Hurricane SC gave the greatest reduction in weed levels out of the pre-emergence options, reducing weed cover by 77% to a mean of 26.2% across all treated plots by 28th August. AHDB 9998 also performed well as it gives good control of mayweed and groundsel which were key weeds at Site 1, as well as cranesbill, and a little fumitory.

All the post-emergence products, with the exception of Hurricane SC 0.05 L/ha gave a significant reduction in weed cover for up to nine weeks after application. Sencorex Flow, Emerger, or Sencorex Flow in a tank mix with Emerger gave a weed reduction of greater than 70%. Sencorex Flow applied alone at 0.3 L/ha at one to two true leaves, and then again at 0.5 L/ha at four to five true leaves, after a pre-emergence application of Anthem reduced weed levels to 11.3% and the addition of Emerger gave no significant increase in weed control, but did increase the level of scorch. Therefore, depending on the weed spectrum present, it may be safer and more cost-effective to apply each product alone rather than in a tank-mix. Chlorpropham, AHDB 9993 and AHDB 9981 also gave significant weed

control, but their efficacy was lower than the best performing products with a percentage weed reduction of 36–44%.

There were no persistent foliar effects from any of the treatments at either site at eight weeks after the final post-emergence application. However, there were some transient crop effects which occurred at one week after the first post-emergence application. The plots affected were those where either post-emergence Emerger, Hurricane SC, AHDB 9981 or Sencorex Flow + Emerger were applied. Emerger gave yellow spotting which persisted for up to two weeks after application, AHDB 9981 gave a slight yellowing in patches on the leaves, and when Sencorex Flow was applied post-emergence in a tank-mix with Emerger this caused scorch and stunting of the crop. At Site 2 only, Hurricane SC caused transient interveinal chlorosis.

There were no significant reductions in plant population at Site 1 for most of the treatments, with the exception of the pre-emergence treatments Anthem + Flexidor 500 0.075 L/ha and Anthem + Sencorex 0.15 L/ha at the assessment at three weeks after the pre-emergence application. In these treatments, plant population was reduced by up to 17%. At this point of assessment most of the crop was at two true leaves. However, significant differences were not seen at the 2nd plant count assessment, suggesting that the crop recovered from the treatments, with the exception that there was still a trend for plots treated with Anthem + Flexidor to have a lower plant population. There were no significant reductions or differences in plant population from any of the treatments applied at Site 2.

There were no strong statistical differences in the fanging assessments, and levels were below 5% across all treatments. There was a trend at both sites for slightly higher numbers of fanging where Hurricane SC had been applied at a post-emergence timing, or AHDB 9998 applied at a pre-emergence timing.

Hurricane SC, Emerger, AHDB 9998, AHDB 9918 and AHDB 9917 would be useful additions to carrot growers' weed control programs at pre-emergence and EAMUs have been obtained for Hurricane SC and Emerger. At post-emergence, Sencorex Flow, Emerger, AHDB 9981 and AHDB 9993 would improve weed control. Sencorex Flow is already approved and was one of the best performing products, so could be included in programmes immediately. As post-emergence options are very limited for carrot growers, further authorisations for other products are also needed to prevent reliance on one mode of action and allow growers to control weeds effectively in a long season crop.

It should be noted that three of the authorised products (Emerger, Hurricane and Gamit) contain active ingredients (aclonifen, diflufenican and clomazone) with similar modes of action from Group F of the herbicides. These are 'bleachers' and act on the inhibition of pigment synthesis. The products have not been tank-mixed in this trial, but it is likely that combining them will increase the bleaching effect and care should be taken.

Conclusions

- At pre-emergence, products Emerger (aclonifen) 1.5 L/ha, Hurricane SC (diflufenican) 0.1 L/ha, Sencorex Flow (metribuzin) 0.15 L/ha, AHDB 9998, AHDB 9918 and AHDB 9917 gave a significant reduction in weed cover for up to 14 weeks after application.
- Anthem + Hurricane SC gave the greatest reduction in weed levels at pre-emergence, reducing weed cover by 77% compared to the untreated control.
- Anthem + Flexidor 0.075 L/ha applied pre-emergence reduced the plant population by 17%.
- All the post-emergence products, with the exception of Hurricane SC 0.05 L/ha, gave a significant reduction in weed cover for up to nine weeks after application.
- Sencorex Flow, Emerger or Sencorex Flow in a tank mix with Emerger gave a weed reduction of greater than 70%. Sencorex Flow applied at 0.3 L/ha at one to two true leaves, and then again at 0.5 L/ha at four to five true leaves, after a pre-emergence application of Anthem reduced weed levels to 11.3% and the addition of Emerger gave no significant increase in weed control, but did increase the level of scorch.

- There were no persistent foliar effects from any of the treatments at eight weeks after the final post-emergence application. However, there were some transient crop effects which occurred at one week after the first post-emergence application. The plots affected were those where either post-emergence Emerger, Hurricane SC, AHDB 9981 or Sencorex Flow + Emerger were applied.

Acknowledgements

AHDB for funding the work, and also the crop protection companies for their financial contributions as well as providing samples for the trials. Thanks should also be given to those who provided sites and crops for the trials as well as technical input, particularly Pete Saunders, of Alan Bartlett & Sons, and Ian Holmes, of Strawson Ltd.

Appendix

a. Photos of crop effects



Yellow spotting from Emerger at 1 week after the first post-emergence application – 21st June



Bleaching from Hurricane SC at 1 week after the first post-emergence application – 21st June



Appearance of trial at 3rd August 2019 – site 1 - Norfolk

b. Crop diary – events related to growing crop

a. Site 1

Crop	Cultivar	Drilling date	Bed width
Carrots	Octavo	20/05/2018	80", 4 triple lines, 13" row spacing

Previous cropping

Year	Crop
2017-18	Radish cover crop
2017	Forage rye
2016	Tulips/rye
2015	Winter wheat

Active ingredients(s)/fertiliser(s) applied to trial area

Date	Product	Rate
13/11/2017	Laws 0N-90P-140K-160NaO-60MgO-2B-20SO3-40CaO	915 kg/ha
21/06/2018	Laws – 16-0-16+ (50N-0P-50k-15MgO-40SO3-1B)	312 kg/ha
23/06/2018	Opte Man DF	1 kg/ha
06/07/2018	Master Magnesium + TE	2.5 kg/ha
06/07/2018	Quark	0.8 L/ha
18/07/2018	OptE B	1.5 L/ha
18/07/2018	Opte Man DF	2.0 kg/ha
18/07/2018	Master Magnesium + TE	2.5 kg/ha
18/07/2018	Headland Copper – Trace Element	2.0 L/ha
08/08/2018	Opte Man DF	2.0 kg/ha
08/08/2018	Master Magnesium + TE	2.5 kg/ha
22/08/2018	Opte Man DF	2.0 kg/ha
22/08/2018	Master Magnesium + TE	2.5 kg/ha
22/08/2018	Zinic	1.5 L/ha
05/09/2018	Feeder K	2.5 L/ha
05/09/2018	Master Magnesium + TE	2.5 kg/ha
05/09/2018	Opte Man DF	4.0 kg/ha

Pesticides applied to trial area

Date	Product	Rate
21/05/2018	Vydate 10G	30 kg/ha
23/06/2018	Decis Protech	0.5 L/ha
23/06/2018	Clayton Cayman	0.4 L/ha
06/07/2018	Cleancrop Feudal	1.9 kg/ha
06/07/2018	Movento	0.3 L/ha
18/07/2018	Cleancrop Feudal	1.9 kg/ha
18/07/2018	Coragen	0.175 L/ha
01/08/2018	SL 567A	1.3 L/ha
08/08/2018	Signum	0.75 kg/ha
08/08/2018	Cleancrop Argent	0.075 L/ha
08/08/2018	Teppeki	0.14 kg/ha
22/08/2018	Hallmark With Zeon Technology	0.143 kg/ha
22/08/2018	Amistar Top	0.95 L/ha
05/09/2018	Hallmark With Zeon Technology	0.143 L/ha
05/09/2018	Reflect	0.95 L/ha

Details of irrigation regime

Date	Type, rate and duration	Amount applied (mm)
24/05/2018		12
18/06/2018		25
28/06/2018		25
04/07/2018		25
08/07/2018		25
16/07/2018		25
23/07/2018		25
06/08/2018		25
28/08/2018		25

b. Site 2

Crop	Cultivar	Drilling date	Bed width
Carrots	Nairobi	12/5/18	62.5mm between individual rows

Previous cropping

Year	Crop
2017	Winter Wheat
2016	
2015	

Active ingredients(s)/fertiliser(s) applied to trial area

Date	Product	Rate	Unit
23/2/18	Omex 0:4:13:4:13Na ₂ O	1350	kg/ha
23/2/18	Omex Boron	2	Kg/ha

Pesticides applied to trial area

Date	Product	Rate	Unit
1/6/18	Biscaya	0.4	L/ha
1/6/18	Decis Protech	0.5	L/ha
7/6/18	Clayton Tine	1.3	L/ha
15/6/18	Decis Forte	0.075	L/ha
15/6/18	Movento	0.3	L/ha
29/6/18	Teppeki	0.14	L/ha
12/7/18	Rudis	0.4	L/ha
12/7/18	Movento	0.3	L/ha
12/7/18	Decis Forte	0.075	L/ha
27/7/18	Amistar Top	1.0	L/ha
27/7/18	Biscaya	0.4	L/ha
27/7/18	Hallmark Zeon	0.15	L/ha
10/8/18	Rudis	0.4	L/ha
10/8/18	Hallmark Zeon	0.15	L/ha
25/8/18	Nativo	0.3	L/ha
25/8/18	Hallmark Zeon	0.15	L/ha
8/9/18	Rudis	0.4	L/ha
22/9/18	Amistar Top	1.0	L/ha
27/10/18	Clayton Spigot	1.0	L/ha

Details of irrigation regime

Date	Type, rate and duration	Amount applied (mm)
June 2018	Overhead Rain Gun	2 x 25mm
July 2018	Overhead Rain Gun	4 x 25mm
August 2018	Overhead Rain Gun	3 x 25mm
September 2018	Overhead Rain Gun	2 x 25mm

- c. Table showing sequence of events by date – this relates to treatments and assessments.

Site 1:

Date	Event
25/05/2018	Timing A treatment application.
15/06/2018	Timing C treatment application. Trial assessment – crop phyto, weed cover and crop emergence counts.
21/06/2018	Trial assessment – crop phyto, weed cover and crop population counts.
28/06/2018	Timing D treatment application. Trial assessment – crop phyto, weed cover and crop population counts.
17/07/2018	Trial assessment – crop phyto, weed cover.
30/07/2018	Trial assessment – crop phyto, weed cover.
28/08/2018	Trial assessment – crop phyto, weed cover.
25/09/2018	Trial plots harvested.

Site 2:

Date	Event
12/05/2018	Timing A treatment application.
19/05/2018	Timing B treatment application.
08/06/2018	Trial assessment – crop phyto, weed cover and crop population counts.
12/06/2018	Timing C treatment application.
18/06/2018	Trial assessment – crop phyto.
04/07/2018	Timing D treatment application. Trial assessment – crop phyto, weed cover.
20/07/2018	Trial assessment – crop phyto, weed cover and crop population counts.
13/08/2018	Trial assessment – crop phyto, weed cover.
29/08/2018	Trial assessment – crop phyto, weed cover.
09/10/2018	Trial plots harvested.

- d. Climatological data during study period

Site 1

Date	Temperature °C (minimum)	Temperature °C (maximum)	Relative humidity % (average)
23/05/2018	10.0	22.0	68.3

Date	Temperature °C (minimum)	Temperature °C (maximum)	Relative humidity % (average)
24/05/2018	9.5	22.5	81.3
25/05/2018	12.0	22.0	89.8
26/05/2018	12.0	24.0	82.1
27/05/2018	13.0	28.5	72.3
28/05/2018	12.5	25.0	81.7
29/05/2018	12.0	16.0	90.3
30/05/2018	12.0	18.0	93.2
31/05/2018	14.0	23.5	91.1
01/06/2018	13.5	24.5	86.6
02/06/2018	16.5	22.0	93.2
03/06/2018	15.0	24.0	90.5
04/06/2018	13.0	16.5	90.1
05/06/2018	10.5	18.0	80.3
06/06/2018	9.5	22.0	76.5
07/06/2018	10.5	22.0	75.9
08/06/2018	12.5	18.5	79.5
09/06/2018	13.0	17.5	80.4
10/06/2018	11.0	23.5	74.9
11/06/2018	8.5	27.5	68.5
12/06/2018	11.5	19.5	74.1
13/06/2018	9.0	22.5	71.7
14/06/2018	12.0	24.5	67.8
15/06/2018	10.0	25.5	64.1
16/06/2018	12.0	21.0	73.1
17/06/2018	11.0	20.0	74.7
18/06/2018	15.5	26.5	71.1
19/06/2018	16.0	24.5	81.1
20/06/2018	14.5	24.0	79.8
21/06/2018	9.5	18.0	68.2
22/06/2018	8.5	20.0	66.6
23/06/2018	7.5	25.0	67.8
24/06/2018	8.0	27.5	69.9
25/06/2018	11.0	29.0	67.9
26/06/2018	8.5	31.5	68.0
27/06/2018	12.0	25.5	78.8
28/06/2018	11.0	25.5	82.1
29/06/2018	11.5	23.0	80.1
30/06/2018	13.5	25.0	69.8
01/07/2018	12.5	27.0	64.3
02/07/2018	11.5	28.0	59.8
03/07/2018	11.0	23.5	70.2
04/07/2018	8.5	25.5	72.4
05/07/2018	12.0	30.0	72.5
06/07/2018	14.0	27.5	76.6
07/07/2018	14.5	29.0	75.2

Date	Temperature °C (minimum)	Temperature °C (maximum)	Relative humidity % (average)
08/07/2018	12.5	31.0	72.5
09/07/2018	14.0	28.5	75.4
10/07/2018	13.0	20.5	77.8
11/07/2018	14.5	19.0	83.9
12/07/2018	12.0	19.0	85.8
13/07/2018	10.0	26.5	83.5
14/07/2018	11.5	29.5	74.0
15/07/2018	13.5	32.0	69.3
16/07/2018	13.0	34.0	67.0
17/07/2018	15.0	28.5	67.3
18/07/2018	12.5	33.5	66.3
19/07/2018	14.5	28.0	72.5
20/07/2018	13.5	27.0	77.7
21/07/2018	16.0	28.5	81.8
22/07/2018	15.0	29.5	80.0
23/07/2018	16.0	34.0	70.8
24/07/2018	17.5	35.5	64.0
25/07/2018	17.0	34.5	64.3
26/07/2018	17.5	34.5	71.1
27/07/2018	18.5	32.0	88.8
28/07/2018	14.5	22.5	82.9
29/07/2018	14.0	20.5	89.3
30/07/2018	15.5	24.5	84.0
31/07/2018	15.5	25.5	83.6
01/08/2018	13.0	28.0	81.3
02/08/2018	13.5	31.0	83.0
03/08/2018	16.5	32.0	85.5
04/08/2018	15.0	25.5	85.1
05/08/2018	13.0	32.0	74.2
06/08/2018	15.0	33.5	73.1
07/08/2018	16.5	29.5	81.7
08/08/2018	16.0	25.0	76.9
09/08/2018	13.5	18.0	94.0
10/08/2018	11.0	18.5	94.0
11/08/2018	9.5	22.5	84.4
12/08/2018	16.0	20.0	92.4
13/08/2018	16.0	22.0	95.8
14/08/2018	15.5	22.5	93.0
15/08/2018	14.5	24.0	88.4
16/08/2018	13.5	18.5	92.8
17/08/2018	10.5	20.5	88.9
18/08/2018	14.5	21.5	89.1
19/08/2018	16.5	21.0	91.4
20/08/2018	17.0	24.5	91.4
21/08/2018	16.5	23.5	91.6

Date	Temperature °C (minimum)	Temperature °C (maximum)	Relative humidity % (average)
22/08/2018	14.0	24.5	90.9
23/08/2018	14.5	20.0	92.1
24/08/2018	10.5	18.5	92.3
25/08/2018	10.0	17.5	92.0
26/08/2018	9.0	16.5	95.6
27/08/2018	13.0	19.0	93.7
28/08/2018	14.5	18.0	92.9
29/08/2018	14.0	18.0	95.3
30/08/2018	10.5	19.5	91.8
31/08/2018	6.0	22.0	89.9
01/09/2018	10.5	24.0	86.6
02/09/2018	11.0	24.5	84.8
03/09/2018	8.5	22.5	92.0
04/09/2018	11.0	18.0	93.8
05/09/2018	13.5	19.0	93.6
06/09/2018	12.0	20.0	94.3
07/09/2018	9.5	16.5	93.5
08/09/2018	10.0	16.0	94.8
09/09/2018	13.0	21.0	91.8
10/09/2018	12.5	18.5	89.0
11/09/2018	15.0	18.0	92.6
12/09/2018	10.0	16.0	96.8
13/09/2018	7.5	18.0	94.6
14/09/2018	11.0	17.5	91.0
15/09/2018	10.0	20.0	90.7
16/09/2018	12.0	22.5	87.8
17/09/2018	15.0	23.0	86.7
18/09/2018	14.0	22.5	81.7
19/09/2018	15.0	23.5	81.3
20/09/2018	13.0	17.5	93.0
21/09/2018	9.0	16.5	89.4
22/09/2018	9.0	14.5	92.9
23/09/2018	8.5	12.5	95.6
24/09/2018	6.5	16.0	90.4
25/09/2018	4.5	22.5	79.2

Site 2: Blyth weather

Date	Temperature °C (average)	Relative Humidity % (average)	Rainfall (mm)
01-May-18	8.9	66.4	0
02-May-18	9.2	77.7	8.4
03-May-18	9.6	75.8	0
04-May-18	12.6	79.7	0
05-May-18	14.5	79	0
06-May-18	15.8	74.4	0
07-May-18	17	73.8	0

Date	Temperature °C (average)	Relative Humidity % (average)	Rainfall (mm)
08-May-18	15.6	79.9	0
09-May-18	12.1	77.4	0
10-May-18	11	73.8	3.2
11-May-18	10.9	73.5	0
12-May-18	12.5	79.5	6.6
13-May-18	12.6	73.4	3.6
14-May-18	12.5	66.6	0
15-May-18	14.2	71.4	0
16-May-18	11.1	77.4	0
17-May-18	8.8	78	0
18-May-18	10.3	75.9	0
19-May-18	13.3	69.2	0
20-May-18	15	70.4	0
21-May-18	14.6	74.4	0
22-May-18	13.2	79.1	0
23-May-18	12.6	77.2	0
24-May-18	13.4	77.7	0.6
25-May-18	11.6	98.7	6.4
26-May-18	14.9	81.7	0
27-May-18	16.9	76.2	0
28-May-18	16.9	84.8	0
29-May-18	15.2	89	0
30-May-18	13.3	98.1	8.4
31-May-18	16.5	93.6	0
01-Jun-18	17.2	89.8	0
02-Jun-18	17	94.1	2
03-Jun-18	18.6	82.5	0
04-Jun-18	14.5	91.5	0
05-Jun-18	14	78.5	0
06-Jun-18	12.3	86.7	0
07-Jun-18	13.6	81	0
08-Jun-18	13.4	90.1	4.8
09-Jun-18	14.7	83.2	0
10-Jun-18	14.3	85.4	0
11-Jun-18	16.1	78.8	2.4
12-Jun-18	14.1	82.1	0
13-Jun-18	16.1	73.9	0.8
14-Jun-18	16.2	69	0.8
15-Jun-18	14	71.7	0
16-Jun-18	14	80.8	3.4
17-Jun-18	14.8	81.3	0.2
18-Jun-18	17.8	74.3	0
19-Jun-18	18.4	74.3	0
20-Jun-18	17.8	70.9	0
21-Jun-18	13.7	61	0
22-Jun-18	15.2	55.4	0
23-Jun-18	14.5	59.8	0

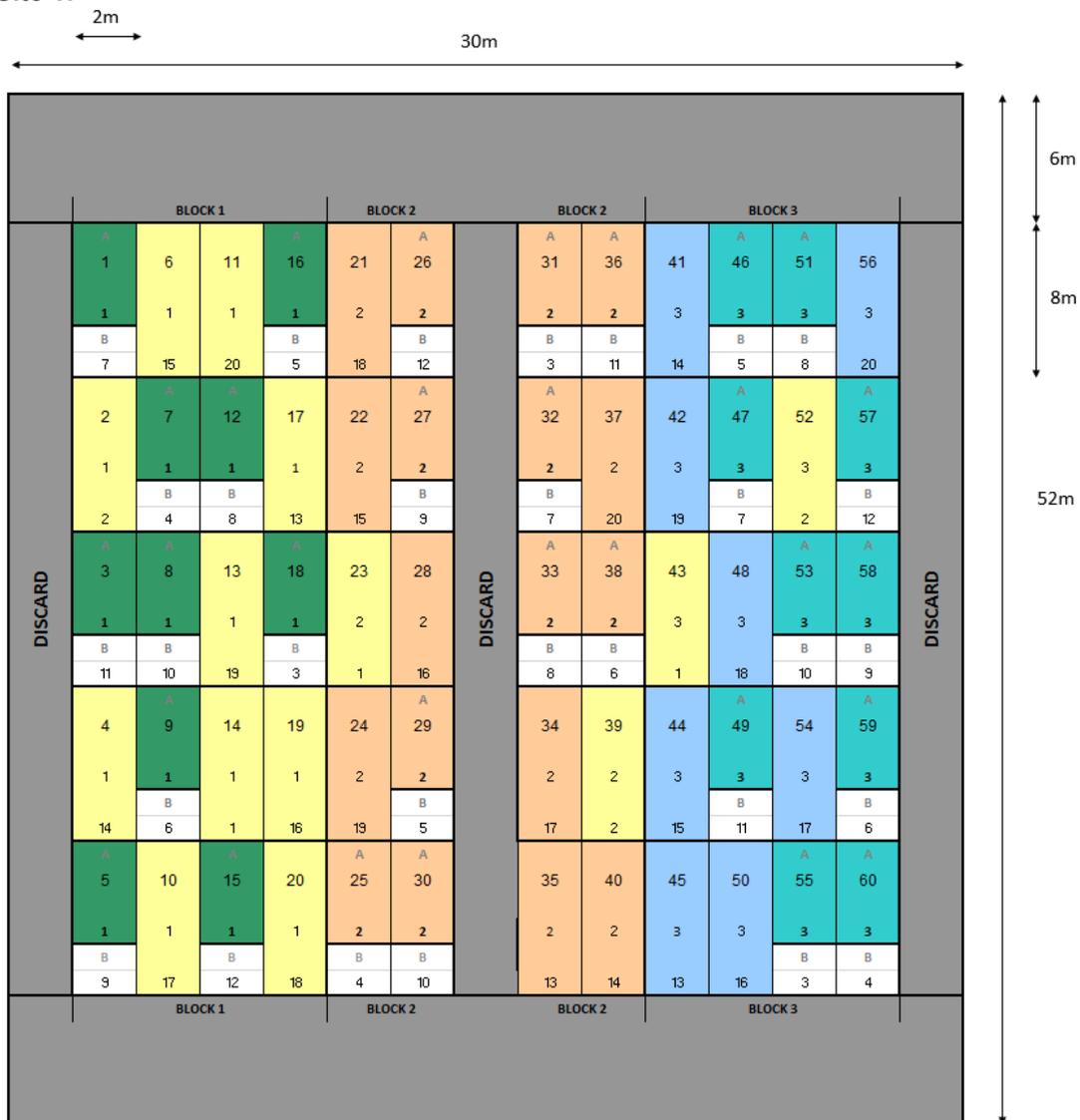
Date	Temperature °C (average)	Relative Humidity % (average)	Rainfall (mm)
24-Jun-18	16.6	64.2	0
25-Jun-18	18.8	60.3	0
26-Jun-18	18.1	62.4	0
27-Jun-18	16.1	74.3	0
28-Jun-18	17.8	68.1	0
29-Jun-18	17.6	72.4	0
30-Jun-18	18	67.1	0
01-Jul-18	18.3	67.3	0
02-Jul-18	18.3	64	0
03-Jul-18	16.4	73.9	0
04-Jul-18	17.3	66.8	0
05-Jul-18	19.6	67.9	0
06-Jul-18	20.6	64.9	0
07-Jul-18	20.1	68.7	0
08-Jul-18	20.3	67.8	0
09-Jul-18	17.4	81.1	0
10-Jul-18	16.9	69	0
11-Jul-18	16	76.6	0
12-Jul-18	16.7	77.7	0
13-Jul-18	16.3	79.9	1.2
14-Jul-18	19.4	72.8	0.2
15-Jul-18	20.1	64.5	0
16-Jul-18	20.1	67	0
17-Jul-18	17.8	63.6	0
18-Jul-18	18.6	62.2	0
19-Jul-18	19.8	62.5	0
20-Jul-18	17.1	70	0.2
21-Jul-18	17.8	76.6	0.2
22-Jul-18	20.1	71.5	0
23-Jul-18	23.5	68.6	0
24-Jul-18	21.3	68.4	0
25-Jul-18	19.3	61.4	0
26-Jul-18	21.4	76.1	6.6
27-Jul-18	21.8	81.5	9
28-Jul-18	16.8	76.2	1.8
29-Jul-18	16.1	94	6.2
30-Jul-18	17.9	81.5	0.2
31-Jul-18	17.4	73.5	4.2
01-Aug-18	17.3	73.3	0
02-Aug-18	21.3	70	0
03-Aug-18	20.7	78.6	0
04-Aug-18	19.4	70.4	0
05-Aug-18	19.5	72	0
06-Aug-18	20.2	71.5	0
07-Aug-18	20.5	71.4	0
08-Aug-18	16.7	67.2	0
09-Aug-18	15	70.3	0

Date	Temperature °C (average)	Relative Humidity % (average)	Rainfall (mm)
10-Aug-18	13.3	69.7	0
11-Aug-18	15.3	70.8	1.2
12-Aug-18	17.2	91.9	2.4
13-Aug-18	18.3	83.2	0
14-Aug-18	18.7	72.3	0
15-Aug-18	19.8	74.7	0
16-Aug-18	16.6	76.5	4.2
17-Aug-18	15.1	75.2	0
18-Aug-18	19.4	72.8	0
19-Aug-18	19.1	79.8	0
20-Aug-18	19.1	81	0
21-Aug-18	20.1	75	0
22-Aug-18	18.9	77.9	0.4
23-Aug-18	14.2	83.5	10.2
24-Aug-18	12.1	80.5	5.8
25-Aug-18	12.9	70.8	0
26-Aug-18	11.6	95.2	8.4
27-Aug-18	15.1	79.6	0
28-Aug-18	15.8	78.1	0
29-Aug-18	15.5	75.5	0
30-Aug-18	13.1	70.8	0
31-Aug-18	12.7	75.9	0
01-Sep-18	15.3	77	0
02-Sep-18	18.3	65.8	0
03-Sep-18	16.7	76.4	0
04-Sep-18	13.5	86	0
05-Sep-18	13.3	86.1	0
06-Sep-18	10.8	87.9	2.8
07-Sep-18	11.2	80.2	0.2
08-Sep-18	12.9	89.8	4.6
09-Sep-18	15.8	80.9	0
10-Sep-18	14.4	76	0
11-Sep-18	16.4	73.3	0.6
12-Sep-18	12.4	78.2	2.4
13-Sep-18	12.6	72.3	0
14-Sep-18	13.2	82.3	1.2
15-Sep-18	14.2	78.8	0
16-Sep-18	16.1	83.5	2.4
17-Sep-18	16.8	87.3	0.4
18-Sep-18	17.6	76.9	1.4
19-Sep-18	16.5	72.3	0
20-Sep-18	13.2	91.7	26.6
21-Sep-18	11.4	79.3	3.4
22-Sep-18	10.2	84.2	0
23-Sep-18	8.9	83.2	0.2
24-Sep-18	9.2	76.1	0
25-Sep-18	9.5	75.3	0

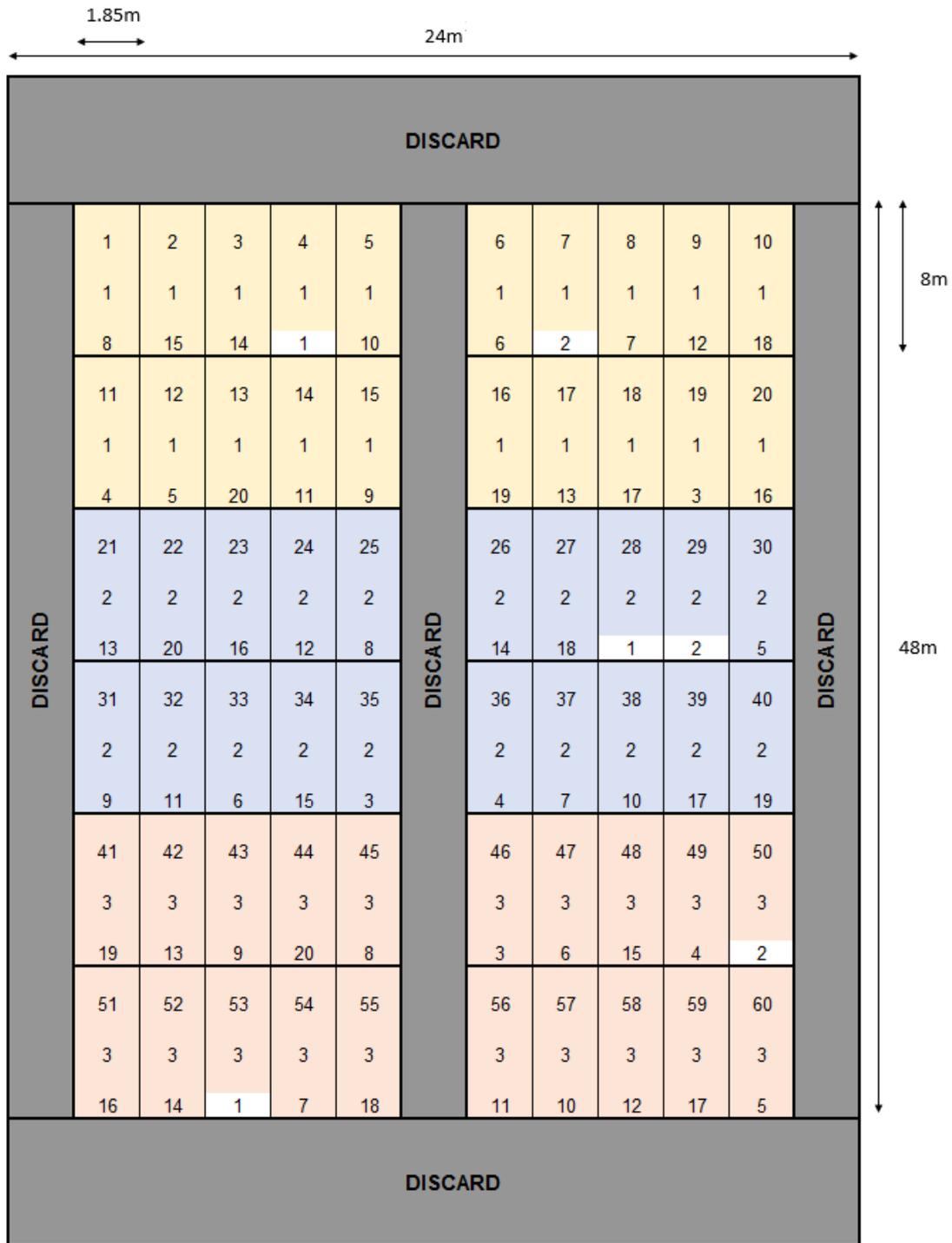
Date	Temperature °C (average)	Relative Humidity % (average)	Rainfall (mm)
26-Sep-18	16.2	77.1	0
27-Sep-18	16.7	75.9	0
28-Sep-18	9.7	77.6	0
29-Sep-18	8.8	80	0
30-Sep-18	9.8	79.1	0

e. Trial design

Site 1:



Site 2:



f. ORETO certificate



Certificate of

**Official Recognition of Efficacy Testing Facilities
or Organisations in the United Kingdom**

This certifies that

RSK ADAS Ltd

complies with the minimum standards laid down in
Regulation (EC) 1107/2009 for efficacy testing.

The above Facility/Organisation has been officially
recognised as being competent to carry out efficacy trials/tests
in the United Kingdom in the following categories:

**Agriculture/Horticulture
Stored Crops
Biologicals and Semiochemicals**

Date of issue: 1 June 2018
Effective date: 18 March 2018
Expiry date: 17 March 2023

Signature

Alison Richardson
Authorised signatory

Certification Number

ORETO 409


HSE
Chemicals Regulation Division

 Department of
**Agriculture and
Rural Development**