SCEPTREPLUS

Final Trial Report

Trial code:	SP01. 2018 (Parsnip)
Title:	AHDB SCEPTREplus parsnip herbicide screens
Crop	Group: Field vegetables – Parsnip (apiaceae), other umbelliferous root vegetables
Target	General broadleaf weeds and grasses, 3WEEDT
Lead researcher:	EPPO1/99(3) Weeds in root vegetables
Organisation:	Angela Huckle
Period:	RSK ADAS
Report date:	1st December 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

9th December 2019
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 metamitron. It formed the basis of commercial programs and was used in tank mixes 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 With linuron now withdrawn (3rd June 2018), this leaves growers with only pendimethalin and metamitron for pre-emergence weed control for autumn 2018.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 post-emergence applications (up to 3TL) 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. With metribuzin and clomazone also not safe to use in parsnips, this leaves the crop particularly short of herbicides—particularly post-emergence—and weed control will be challenging for growers.

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

Method

Two separate trials were sited at commercial parsnip grower sites on freely draining loamy soils – one in Suffolk 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. Some plots had split treatment timings – this is detailed in the paragraph below, and illustrated in the appendix.

Treatments were applied at four timings, either in tank-mix combinations pre-emergence 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). Applications were with a 2m boom and Oxford Precision Sprayer backpack, at 200 L/ha water volume.

Each plot was assessed for crop safety on six occasions at Site 1, and on two occasions at Site 2. Crop safety became difficult to assess after the middle of July due to confounding stunting effects from the high weed burden in many plots. Treatment efficacy was assessed on six occasions at both sites; as % weed cover at Site 1 in Suffolk, and weed counts and % weed cover at Site 2 in Notts. In addition, plant counts for establishment were made twice, and an assessment to record % root fanging was completed at harvest at Site 2 in selected plots.

Results and discussion

The weed spectrums at both sites were similar, but the proportions of the main weed species at each site were different. At Site 1, black bindweed and fat hen were dominant, with a little groundsel and some volunteer oilseed rape, knotgrass, cranesbill, fumitory and volunteer potatoes. At Site 2 there was mainly redshank and black bindweed with a greater amount of groundsel than Site 1, with a little fat hen and fumitory.

Although there were significant reductions in percentage weed cover at each site, these differences in species proportions highlighted some differences in product performance. For example, Anthem 3.3 L/ha + Hurricane SC 0.1 L/ha gave a significant reduction in percentage weed cover at Site 1, but was not one of the best performing products at Site 2. There was a higher proportion of groundsel at Site 2 and Hurricane SC has a weakness on groundsel control, accounting for the difference. Therefore, although a number of products gave a significant reduction in percentage weed cover compared to the untreated control, consideration needs to be given to target the weed species present at the site to gain the greatest efficacy as many of the novel products in the trial have narrower weed spectrums.

The lower persistence of efficacy at **Site 1** due to the restricted irrigation at the site in a dry spring also shows the importance of moisture for pre-emergence residual herbicides to work to their full potential. At this site, only three pre-emergence treatments gave statistically significant reductions in weed cover at eleven weeks after application at the end of July. These were; Anthem 3.3 L/ha + Hurricane 0.1 L/ha, Anthem + AHDB9998 and Anthem + AHDB9999. Despite being significantly reduced, weed cover was still between 43% and 61% in these treatments which would still be at a level to cause yield reduction.

However, at earlier assessments all pre-emergence treatments gave significant control of the weeds present for up to six weeks after application, and at this point reduced weed levels by at least 43% when compared to the untreated control. With the exception of Flexidor 500 and AHDB9918, all the tank-mix partners added a further 20.5-28.8% weed control over Anthem applied alone. Therefore Emerger, Hurricane SC, chlorpropham, AHDB9998, AHDB9999 and AHDB9917 would be useful alternative tank-mix partners to Goltix (metamitron).

At **Site 2**, seven pre-emergence treatments and the standard Anthem 3.3 L/ha gave a significant reduction in the percentage of weed cover for up to fifteen weeks after application. These were Anthem with the addition of the following in a tank-mix; Goltix, Emerger, chlorpropham, Flexidor 500, AHDB9998, AHDB9999, or AHDB9917. These treatments also gave 5.1-46.9% greater reduction in weed control than Anthem alone. Anthem 3.3 L/ha + chlorpropham 2.8 L/ha or the coded products AHDB9999 and AHDB9917 were the three best performing pre-emergence products in this trial. This site had access to irrigation and therefore the residual herbicides were able to work more effectively.

The pre-emergence treatments still left a moderate percentage of weed, even after significantly reducing weed levels. As no products are currently authorised for post-emergence use in parsnips, options are urgently required for approval. There are alternative approaches such as inter-row weeding, but conditions are not always appropriate and herbicides are still required. Anthem 3.3 L/ha then Emerger 0.5 L/ha applied twice, Anthem then Stomp 1.5 L/ha + Emerger 0.5 L/ha applied twice and Anthem then Stomp 1.5 L/ha + Hurricane 0.05 L/ha gave significant control at both sites, reducing weed levels by up to 25-34% at Site 1, and 75-86% at Site 2. The lower efficacy at **Site 1** was because it was difficult to time the post-emergence application due to the slow growth of the parsnips and by the time the crop reached the growth stage for the 1st application at two to three true leaves, the weeds had reached small rosette stage (10 cm across) and were harder to control.

Assessment of phytotoxicity at both of the trial sites was difficult after mid-July due to the high weed levels in the plots, and confounding effects of stunting caused by this competition. However, there was no crop loss seen in the assessments completed before this point. The main crop effects seen were chlorosis, scorch or stunting, all of which were likely transient, and not noted at any of the later efficacy assessments.

In the pre-emergence treatments; at the final assessment in July there were no effects seen on the crop at Site 1, and the scores below eight at Site 2 were from stunting caused by increased weed levels in those plots rather than effects from treatments. The only treatment to show a moderate phytotoxicity score at Site 1 was Anthem 3.3 L/ha + Hurricane SC 0.1 L/ha, where interveinal chlorosis was seen at three weeks after the pre-emergence application. This was transient, and the crop had grown through the effect by the next assessment two weeks later.

At four weeks after the final post-emergence application at Site 1, only plots treated with AHDB9981 still showed a crop effect—yellow clouding of leaves. However, this would likely be transient, and crop vigour was unaffected. There were also transient crop effects from Emerger (aclonifen) and Hurricane SC (diflufenican) which occurred after the first post-emergence application and persisted until two weeks after the second post-emergence application. Emerger gave a yellow spotting on the leaves, and Hurricane gave interveinal bleaching or chlorosis and stunting. Only slight traces of these effects were present at a month after the final application, and new growth was unaffected.

There were no significant reductions in plant population at Site 1 at either assessment. At Site 2 there were no significant differences between the untreated and treatments at the first

assessment, and no change in plant population after post-ems were applied at the second assessment. At Site 1, the significant differences at the second assessment were caused by a reduction in the plant population of the untreated due to crop loss from weed competition, and therefore the results of this assessment are confounded.

Table 1. Summary of crop damage and percentage weed cover at key dates (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, 14th July. Weeks in brackets are number of weeks after pre-emergence application.

Trt. No.	Mean crop damage (0-10)		Mean weed cover (%)							
	Site 1	Site 2	22nd Jun (6 weeks)		27th Jul (11 weeks)		29th June (6 weeks)		30th Aug (15 weeks)	
	12th July (9 weeks)	13th July (8 weeks)	Ang	Back-trans	Ang.	Back-trans	Ang.	Back-trans	Ang.	Back-trans
Untreated	9.8	10.0	41.5	44.0	73.8	92.3	51.9	61.9	75.3	93.6
Anthem	8.7	7.3	**31.5**	27.2	66.6	84.3	**10.9**	3.6	**43.0**	46.5
Anthem + Goltix	9.3	8.3	**24.6**	17.3	61.0	76.4	**9.2**	2.5	**37.2**	36.6
Anthem + aclonifen	9.7	9.7	**23.7**	16.2	65.0	82.1	**7.9**	1.9	**40.5**	42.2
Anthem + Hurricane SC	9.7	7.3	**22.4**	14.5	**54.8**	66.7	**14.7**	6.5	63.1	79.5
Anthem + chlorpropham	9.3	7.0	**25.0**	17.9	**59.1**	73.6	**5.9**	1.1	**22.8**	14.9
Anthem + Flexidor 500	8.7	7.3	**30.0**	25.0	69.2	87.4	**8.7**	2.3	**40.8**	42.7
Anthem + AHDB9998	8.3	9.0	**24.0**	16.5	**34.0**	31.2	**7.4**	1.6	**38.0**	37.9
Anthem + AHDB9918	9.3	8.7	**28.7**	23.1	59.7	74.6	**14.5**	6.3	57.4	71.0
Anthem + AHDB9999	9.7	8.3	**22.6**	14.8	**51.0**	60.4	**5.4**	0.9	**34.8**	32.6
Anthem + AHDB9917	9.3	9.3	**23.7**	16.2	**58.9**	73.3	**8.2**	2.0	**34.8**	32.5
Anthem, then (aclonifen) x2	8.0	8.7	32.2	28.3	**50.9**	60.1	**11.3**	3.8	**20.6**	12.4
Anthem, then (Hurricane SC) x2	7.7	6.7	**31.0**	26.4	66.0	83.5	**7.6**	1.7	**38.1**	38.1
Anthem, then (chlorpropham) x2	8.7	9.3	36.2	34.9	63.8	80.5	**8.9**	2.4	**26.6**	20.1
Anthem, then (AHDB9993) x2	9.0	6.7	**30.8**	26.2	63.5	80.1	**9.4**	2.6	**36.9**	36.1
Anthem, then (AHDB9981) x2	6.3	8.0	35.0	32.9	68.9	87.1	**9.9**	3.0	**33.1**	29.9
Anthem, then (Stomp Aqua + aclonifen) x2	9.0	8.0	**31.6**	27.5	**45.5**	50.9	**11.9**	4.3	**24.9**	17.7
Anthem, then (Stomp Aqua +	8.7	7.0	**25.1**	18.0	**56.3**	69.3	**7.9**	1.9	**28.4**	22.6

Trt. No.	Mean crop damage (0-10)		Mean weed cover (%)							
	Site 1	Site 2	22nd Jun (6 weeks)		27th Jul (11 weeks)		29th June (6 weeks)		30th Aug (15 weeks)	
	12th July (9 weeks)	13th July (8 weeks)	Ang	Back-trans	Ang.	Back-trans	Ang.	Back-trans	Ang.	Back-trans
Hurricane SC) x2										
Anthem, then (Stomp Aqua + AHDB9993) x2	8.0	8.3	32.1	28.2	70.3	88.7	**11.4**	3.9	**29.9**	24.9
p value	NS	NS		0.011		0.008		<0.001		<0.001
d.f.	39	39		39		39		39		39
L.S.D.	1.807	3.057		9.622		13.51		9.495		18.36

Conclusion

- At pre-emergence, products Emerger 1.5 L/ha, Hurricane SC 0.1 L/ha, chlorpropham 2.8 L/ha, AHDB9998, AHDB9999 and AHDB9917 gave a significant reduction in percentage weed cover for up to six weeks after application

- AHDB9999 was one of the best performing pre-emergence products in both trials, while Hurricane SC 0.1 L/ha and AHDB9998 performed well at Site 1, and chlorpropham and AHDB9917 performed well at Site 2.

- This indicates that it is important to select the appropriate herbicide for the anticipated target weed spectrum to gain the best efficacy.

- At post-emergence, treatments Emerger 0.5 L/ha and Anthem1.5 L/ha + Emerger 0.5 L/ha and Anthem 1.5 L/ha + Hurricane SC 0.05 L/ha gave a significant reduction in percentage weed cover for up to three weeks after application at Site 1, and seven weeks after application at Site 2.

- There were no reductions in plant population, and no persistent foliar effects. However, there were some transient crop effects after the post-emergence applications from Emerger (aclonifen), Hurricane SC (diflufenican) and AHDB9981. This occurred after the first post-emergence application and persisted until two weeks after the second post-emergence application. Emerger gave a yellow spotting on the leaves, Hurricane gave interveinal bleaching or chlorosis and stunting, and AHDB9981 gave yellow areas on the leaves.

Take home message

Emerger is authorised under EAMU 1601/19 for pre-emergence use on parsnip and is a useful addition to programmes which growers can use immediately, but it has only been tested in tank-mix with pendimethalin, and other mixes would need to be tested carefully before use on a large area of crop. A post-emergence EAMU authorisation for Emerger would also improve weed control, and it was one of the best performing products at this timing.

Authorisations for pre-emergence use of Hurricane SC, chlorpropham, AHDB9998, AHDB9999 and AHDB9917 would improve weed control for parsnip growers, while AHDB9981 and Hurricane SC would be useful post-emergence products to pursue for EAMUs.

Objectives

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 parsnips, compared with the commercial standard pre-emergence tank-mix (pendimethalin).

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 PP1/181(4)	Conduct and reporting of efficacy evaluation trials including good experimental practice	None
EPPO PP1/214(3)	Principles of acceptable efficacy	None
EPPO PP1/224(2)	Principles of efficacy evaluation for minor uses	None
EPPO PP1/225(2)	Minimum effective dose	None
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: off Fordham Rd Freckenham Suffolk IP28 8JB Grid reference: TL 65900 72200	**Site 2** Field: off A60 T. Hammond & sons New Farm Arnold, Nottingham NG5 8PB Grid reference: SK 57017 50030
Crop	Parsnip	
Cultivar	Javelin	
Soil or substrate type	Freely draining lime-rich loamy soils	Freely draining slightly acid sandy soils
Agronomic practice	See Appendix	
Prior history of site	See Appendix	

Trial design

Item	**Details**
Trial design:	Fully randomised block
Number of replicates:	3
Row spacing:	72" beds (4 double lines, 13" row spacing)
Plot size: (w x l)	2 m x 8 m
Plot size:	16 m^2
Number of plants per plot:	N/K

Treatment details

AHDB Code	Product name	Active substance	Formulation batch number	Content of active substance (g/L)	Formulation type
N/A	Anthem	pendimethalin	N/K	400	Suspension Concentrate
aclonifen	Emerger	aclonifen	EV56006446	600	Suspension Concentrate
AHDB9917	N/D	N/D	N/D	N/D	N/D
AHDB9993	N/D	N/D	N/D	N/D	N/D
AHDB9999	N/D	N/D	N/D	N/D	N/D
AHDB9998	N/D	N/D	N/D	N/D	N/D
N/A	Flexidor 500	isoxaben	F006H41002	500	Suspension Concentrate
N/A	Goltix	metamitron	17108259	700	Suspension Concentrate
N/A	Hurricane SC	diflufenican	15068154	500	Suspension Concentrate
chlorpropham	Intruder	chlorpropham	543H	400	Emulsifiable Concentrate
AHDB9981	N/D	N/D	N/D	N/D	N/D
N/A	Stomp Aqua	pendimethalin	0016724770	455	Capsule Suspension
AHDB9918	N/D	N/D	N/D	N/D	N/D

Application schedule

Trt. No.	Treatment: product name or AHDB code	Rate of active substance(s) (g/ha)	Rate of product (L/ha)	Timing
1	Untreated	-	-	N/A
2	Untreated	-	-	
*3	Anthem	1320	3.3	A, B
4	Anthem + Goltix	1320 1400	3.3 2.0	
5	Anthem + Emerger	1320 900	3.3 1.5	
6	Anthem + Hurricane SC	1320 50	3.3 0.1	
7	Anthem + chlorpropham	1320 1120	3.3 2.8	
8	Anthem + Flexidor 500	1320 37.5	3.3 0.075	
9	Anthem + AHDB9998	1320 1344	3.3 1.4	
10	Anthem + AHDB9918	1320 240	3.3 0.48	
11	Anthem + AHDB9999	1320 800	3.3 1.0	
12	Anthem + AHDB9917	1320 N/K	3.3 0.7	
13	Anthem	1320	3.3	
	Emerger	300	0.5	C
	Emerger	300	0.5	D

Trt. No.	Treatment: product name or AHDB code	Rate of active substance(s) (g/ha)	Rate of product (L/ha)	Timing
14	Anthem	1320	3.3	A
	Hurricane SC	25	0.05	C
	Hurricane SC	25	0.05	D
15	Anthem	1320	3.3	A
	chlorpropham	720	1.8	C
	chlorpropham	720	1.8	D
16	Anthem	1320	3.3	A
	AHDB9993	160	1.0	C
	AHDB9993	160	1.0	D
17	Anthem	1320	3.3	A
	AHDB9981	112.5	0.25	C
	AHDB9981	112.5	0.25	D
18	Anthem	1320	3.3	A
	Stomp Aqua + aclonifen	682.5 300	1.5 0.5	C
	Stomp Aqua + aclonifen	682.5 300	1.5 0.5	D
19	Anthem	1320	3.3	A
	Stomp Aqua + Hurricane SC	682.5 25	1.5 0.05	C
	Stomp Aqua + Hurricane SC	682.5 25	1.5 0.05	D
20	Anthem	1320	3.3	A
	Stomp Aqua + AHDB9993	682.5 160	1.5 1.0	C
	Stomp Aqua + AHDB9993	682.5 160	1.5 1.0	D

* grower standard

Application details

Site 1	Timing A	Timing B	Timing C	Timing D
Application date	09/05/2018	18/05/2018	15/06/2018	28/06/2018
Time of day	09:45 – 11:00	10:44 – 11:00	16:50 – 17:50	15:50 – 16:50
Crop growth stage (Max, min average BBCH)	pre-chit	pre-em	BBCH12 (2TL)	BBCH14 (4TL)
Crop height (cm)	N/A	N/A	5	8
Crop coverage (%)	N/A	N/A	15	30
Application Method	spray	spray	spray	spray
Application Placement	soil	soil	foliar	foliar
Application equipment	Oxford Precision Sprayer (knapsack)	Oxford Precision Sprayer (knapsack)	Oxford Precision Sprayer (knapsack)	Oxford Precision Sprayer (knapsack)
Nozzle pressure	2.4	2.4	2.4	2.4
Nozzle type	Flat fan	Flat fan	Flat fan	Flat fan
Nozzle size	02-F110	02-F110	02-F110	02-F110

Site 1	Timing A	Timing B	Timing C	Timing D
Application date	09/05/2018	18/05/2018	15/06/2018	28/06/2018
Application water volume (L/ha)	200	200	200	200
Temperature of air – shade (°C)	16.2 – 21.0	14.0 – 15.1	20.9 – 21.0	25.7 – 26.0
Relative humidity (%)	62.0 – 63.6	60.1 – 63.7	46.0 – 47.9	51.5 – 52.3
Wind speed range (mph)	2.0 – 7.3	2.6 – 3.3	6.1 – 8.1	5.9
Dew presence (Y/N)	N	N	N	N
Temperature of soil - 10cm (°C)	17.0	14.0	18.9	23.0
Wetness of soil - 2-5 cm	dry	dry	dry	dry
Cloud cover (%)	15	40	N/K	50

Site 2	Timing A	Timing B	Timing C	Timing D
Application date	19/05/2018	31/05/2018	29/06/2018	14/07/2018
Time of day	12:00 – 13:00	10:50 - 12:00	11:00 – 12:00	11:00 – 11:45
Crop growth stage (Max, min average BBCH)	pre-chit	pre-em	BBCH12-13 (2-3TL)	BBCH15-16 (5-6TL)
Crop height (cm)	N/A	N/A	15	30
Crop coverage (%)	N/A	N/A	60	80
Application Method	spray	spray	spray	spray
Application Placement	soil	soil	foliar	foliar
Application equipment	Oxford Precision Sprayer (knapsack)	Oxford Precision Sprayer (knapsack)	Oxford Precision Sprayer (knapsack)	Oxford Precision Sprayer (knapsack)
Nozzle pressure	2.0	2.0	2.0	2.0
Nozzle type	Flat fan	Flat fan	Flat fan	Flat fan
Nozzle size	03-F110	03-F110	03-F110	03-F110
Application water volume (L/ha)	250	250	250	250
Temperature of air – shade (°C)	22.4-23.0	17.6 – 17.8	25.0 – 25.5	25.9 – 26.9
Relative humidity (%)	46.4 -47.0	98.3 – 99.1	44.4 – 45.0	46.5 – 48.4
Wind speed range (mph)	2.7 - 4.0	1.6 - 2.0	2.6 – 3.7	3.5 4.5
Dew presence (Y/N)	N	N	N	N
Temperature of soil - 10cm (°C)	19.4	18.1	24.4	23.3
Wetness of soil - 2-5 cm	Dry	Damp	Dry	Damp
Cloud cover (%)	5	100	0	50

Levels of pests/pathogens at application and through the assessment period (untreated averages)

Site 1

Common name	Scientific Name	EPPO Code	Weed level at first assessment	Weed level mid-assessment period (4 weeks)	Weed level at end of assessment period (15 weeks)
Broad leaved weeds and grasses	*N/A*	3WEEDT	16.9%	29.8%	71.3%

Site 2

Common name	Scientific Name	EPPO Code	Weed level at first assessment	Weed level mid-assessment period (6 weeks)	Weed level at end of assessment period (15 weeks)
Broad leaved weeds and grasses	*N/A*	3WEEDT	125 plants/m^2 (30%)	51.9%	75.3%

Assessment details

Trial 1:

Evaluation date	Evaluation Timing (DA)*	Crop Growth Stage (BBCH)	Evaluation type (efficacy, phytotox)	What was assessed and how (e.g. dead or live pest; disease incidence and severity; yield, marketable quality)
28/05/2018	19	10	efficacy phytotox	Percentage of weed cover (whole plot score) Phytotox (scale 0-10, 0 = Dead) Weed species
06/06/2018	28	11	plant population	Plant counts (count per m as counts of 2 rows either side of a 0.5 m ruler)
14/06/2018	36	12	efficacy phytotox	Percentage of weed cover (whole plot score) Phytotox (scale 0-10, 0 = Dead)
22/06/2018	44	13	efficacy phytotox pop. count	Percentage of weed cover (whole plot score) Phytotox (scale 0-10, 0 = Dead) Plant counts (count per m as counts of 2 rows either side of a 0.5 m ruler)
12/07/2018	64	14	efficacy phytotox	Percentage of weed cover (whole plot score) Phytotox (scale 0-10, 0 = Dead)
27/07/2018	79	42	efficacy phytotox	Percentage of weed cover (whole plot score) Phytotox (scale 0-10, 0 = Dead)
22/08/2018	105	46	efficacy phytotox	Percentage of weed cover (whole plot score) Phytotox (scale 0-10, 0 = Dead)
No harvest assessment for fanging as there was too much weed competition at the final harvest which would have confounded results				

* DA – days after application

Trial 2:

Evaluation date	Evaluation Timing (DA)*	Crop Growth Stage (BBCH)	Evaluation type (efficacy, phytotox)	What was assessed and how (e.g. dead or live pest; disease incidence and severity; yield, marketable quality)
18/06/2018	32	12	efficacy plant population	Weed counts, total and species (3x quadrats) Plant counts (count per m as counts of 2 rows either side of a 0.5 m ruler)
29/06/2018	41	12-13	efficacy phytotox	Percentage of weed cover (whole plot score) Phytotox (scale 0-10, 0 = Dead)
13/07/2018	55	15-16	efficacy phytotox	Percentage of weed cover (whole plot score) Phytotox (scale 0-10, 0 = Dead)
01/08/2018	74	42	efficacy plant population	Percentage of weed cover (whole plot score), Percentage main weed species (3x quadrats) Plant counts (count per m as counts of 2 rows either side of a 0.5 m ruler)
17/08/2018	90	46	efficacy	Percentage of weed cover (whole plot score), Percentage main weed species (3x quadrats)
30/08/2018	103	48	efficacy	Percentage of weed cover (whole plot score), Percentage main weed species (3x quadrats)
26/10/2018	160	49	fanging root quality	No. of fanged roots, and deformed roots at harvest

* DA – days after application

Statistical analysis

The trials had randomised block designs, each with treatments replicated three times. Both comprised twenty treatments, including two untreated controls and a grower standard treatment. Split plots were included, but 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 chitted. 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 each trial—which is not unexpected in field situations—there was a need to transform this data prior to analysis. To determine treatment efficacy, an angular transformation was performed then the back transformed means presented, from which the % reduction in weeds was calculated using Abbotts formula.

All data were analysed by ANOVA using Genstat 18.4 by Emily Lawrence at RSK ADAS.

Results

Phytotoxicity

Phytotoxicity results are presented in Table 2 and 3, 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	90%
2	80%
3	70%
4	60%
5	50%
6	40%
7	30%
*8	20%
9	10%
10	*(no damage)* 0%

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

Assessment of phytotoxicity at both of the trial sites was difficult after mid-July due to the high weed levels in the plots, and confounding effects of stunting caused by this competition. However, there was no crop loss seen in the assessments completed before this point. The main crop effects seen were chlorosis, scorch or stunting, all of which were transient and not noted at any of the later efficacy assessments.

In the pre-emergence treatments; at the final assessment in July there were no effects seen on the crop at Site 1, and the scores below eight at Site 2 were from stunting caused by increased weed levels in those plots rather than effects from treatments. The only treatment to show a moderate phytotoxicity score at Site 1 was Anthem 3.3 L/ha + Hurricane SC 0.1 L/ha, where interveinal chlorosis was seen at three weeks after the pre-emergence application. This was transient, and the crop had grown through the effect by the next assessment two weeks' later.

At four weeks after the final post-emergence application at Site 1, only plots treated with AHDB9981 still showed a crop effect—yellow clouding of leaves. However, this was likely transient, and crop vigour was unaffected. There were also transient crop effects from Emerger (aclonifen) and Hurricane SC (diflufenican) which occurred after the first post-emergence application and persisted until two weeks after the second post-emergence application. Emerger gave a yellow spotting on the leaves, and Hurricane gave interveinal bleaching or chlorosis and stunting. Only slight traces of these effects were present at a month after the final application, and new growth was unaffected.

Table 2. Mean phytotoxicity scores at five dates throughout the Site 1 assessment period. Values which fall under the score of 8 and would be deemed unacceptable are highlighted in **bold**. *(WAT = weeks after treatment)*. Post-emergence treatments applied 15th June and 28th June.

Treatment	Mean crop damage scores				
	28th May (3 weeks)	**14th Jun** (5 weeks)	**22nd Jun** (6 weeks)	**12th Jul** (9 weeks)	**27th Jul** (11 weeks)
Untreated	9.83	10.00	10.00	9.83	10.00
Anthem	9.00	10.00	**7.67**	8.67	9.00
Anthem + Goltix	9.00	8.33	8.00	9.33	9.67
Anthem + aclonifen	8.00	9.33	8.33	9.67	10.00
Anthem + Hurricane SC	**6.00**	9.67	8.00	9.67	10.00
Anthem + chlorpropham	9.00	10.00	8.67	9.33	10.00
Anthem + Flexidor 500	9.00	9.33	**7.33**	8.67	9.00
Anthem + AHDB9998	9.00	8.67	**7.00**	8.33	9.00
Anthem + AHDB9918	9.00	9.33	**7.67**	9.33	10.00
Anthem + AHDB9999	8.33	9.33	8.33	9.67	10.00
Anthem + AHDB9917	8.67	10.00	**7.33**	9.33	10.00
Anthem, then (aclonifen) x2	9.00	9.33	**7.33**	8.00	8.67
Anthem, then (Hurricane SC) x2	9.00	10.00	8.00	**7.67**	8.67
Anthem, then (chlorpropham) x2	9.00	10.00	8.33	8.67	9.67
Anthem, then (AHDB9993) x2	9.00	9.00	8.33	9.00	9.67
Anthem, then (AHDB9981) x2	8.00	10.00	**7.67**	**6.33**	**7.33**
Anthem, then (Stomp Aqua + aclonifen) x2	9.00	8.00	8.33	9.00	9.33
Anthem, then (Stomp Aqua + Hurricane SC) x2	9.00	10.00	8.00	8.67	9.33
Anthem, then (Stomp Aqua + AHDB9993) x2	8.33	10.00	8.00	8.00	9.00
F prob. value	<0.001	NS	<0.001	NS	0.082
d.f.	39	39	39	39	39
L.S.D.	0.9590	1.395	0.8436	1.807	1.349

() = post-emergence treatment

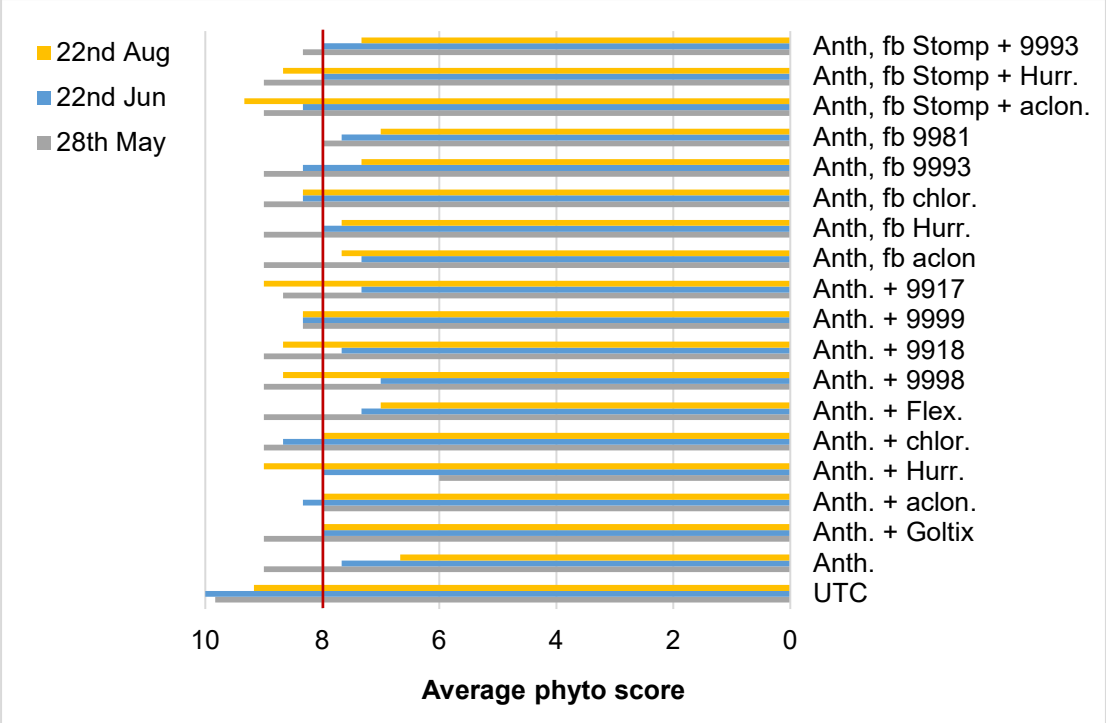


Figure 1. Mean phytotoxicity (0-10) at three assessment dates throughout the trial at Site 1. Scores of 8 or above (marked by red line) deemed acceptable damage.

Table 3. Mean phytotoxicity scores at two dates throughout the Site 2 assessment period. Values which fall under the score of 8 and would be deemed unacceptable are highlighted in **bold**. *(WAT = weeks after treatment)*. Post-emergence treatments applied 29th June and 14th July.

Treatment	Mean crop damage scores	
	29th Jun (6 weeks)	**13thJul** (8 weeks)
Untreated	10.0	10.0
Anthem	9.0	**7.3**
Anthem + Goltix	8.3	8.3
Anthem + aclonifen	8.3	9.7
Anthem + Hurricane SC	8.7	**7.3**
Anthem + chlorpropham	9.0	**7.0**
Anthem + Flexidor 500	8.7	**7.3**
Anthem + AHDB9998	8.3	9.0
Anthem + AHDB9918	8.3	8.7
Anthem + AHDB9999	8.3	8.3
Anthem + AHDB9917	9.0	9.3
Anthem, then (aclonifen) x2	9.7	8.7

Treatment	Mean crop damage scores	
	29th Jun (6 weeks)	**13thJul** (8 weeks)
Anthem, then (Hurricane SC) x2	9.0	**6.7**
Anthem, then (chlorpropham) x2	9.3	9.3
Anthem, then (AHDB9993) x2	8.3	**6.7**
Anthem, then (AHDB9981) x2	8.7	8.0
Anthem, then (Stomp Aqua + aclonifen) x2	9.0	8.0
Anthem, then (Stomp Aqua + Hurricane SC) x2	9.0	**7.0**
Anthem, then (Stomp Aqua + AHDB9993) x2	9.0	8.3
F prob. value	0.012	NS
d.f.	39	39
L.S.D.	0.9688	3.057

Plant population

Results from plant counts are presented in Table 4. There were no significant reductions in plant population at Site 1 at either assessment. At Site 2, there were no significant differences between the untreated and treatments at the first assessment, and no change in plant population after post-ems were applied at the second assessment. At Site 1, the significant differences at the second assessment were caused by a reduction in the plant population of the untreated due to crop loss from weed competition, and therefore the results of this assessment are confounded.

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 double row)			
	Site 1		Site 2	
	6th June (4 weeks)	**22nd June** (6 weeks)	**18th June** (4 weeks)	**1st August** 11 weeks)
Untreated	13.2	19.3	8.5	6.1
Anthem	13.3	20.2	10.0	9.5
Anthem + Goltix	13.2	21.3	9.2	6.7
Anthem + aclonifen	13.5	19.5	10.3	10.3
Anthem + Hurricane SC	12.8	21.2	10.2	7.3
Anthem + chlorpropham	13.5	21.7	10.5	10.3
Anthem +	12.5	19.5	9.7	9.3

Treatment	Plant population counts (plants/m/single row) (counts are from a single row of the central double row)			
	Site 1		Site 2	
	6th June (4 weeks)	22nd June (6 weeks)	18th June (4 weeks)	1st August 11 weeks)
Flexidor 500				
Anthem + AHDB9998	11.2	18.0	10.3	8.5
Anthem + AHDB9918	12.5	18.2	11.0	7.2
Anthem + AHDB9999	13.0	24.5	11.2	11.5
Anthem + AHDB9917	11.8	21.0	10.8	7.8
Anthem, then (aclonifen) x2	*12.7*	20.7	*10.8*	10.2
Anthem, then (Hurricane SC) x2	*13.5*	21.5	*9.2*	8.7
Anthem, then (chlorpropham) x2	*13.3*	21.3	*9.5*	9.5
Anthem, then (AHDB9993) x2	*12.5*	20.0	*8.0*	8.3
Anthem, then (AHDB9981) x2	*12.7*	21.5	*10.0*	9.5
Anthem, then (Stomp Aqua + aclonifen) x2	*14.0*	21.2	*8.8*	8.1
Anthem, then (Stomp Aqua + Hurricane SC) x2	*13.2*	20.0	*10.8*	11.0
Anthem, then (Stomp Aqua + AHDB9993) x2	*11.8*	21.7	*9.8*	8.0
p value	NS	NS	NS	0.005
d.f.	39	39	39	39
L.S.D.	3.016	3.140	2.722	2.784

() post-emergence treatment

Weed control – mean percentage weed cover

Site 1:
Weed cover results are presented in Table 5 and Figure 3. These figures were used to calculate the percent reduction in weed cover compared to the untreated control (using Abbotts formula), and these values are listed in Table 7.

Six treatments gave statistically significant reductions in weed cover up to the fifth assessment at the end of July, at eleven weeks after the pre-emergence application and four weeks after the post-emergence application. These were Anthem 3.3 L/ha + Hurricane 0.1 L/ha, Anthem + AHDB9998, and Anthem + AHDB9999 at pre-emergence; and Anthem 3.3 L/ha then Emerger applied twice, Anthem then Stomp 1.5 L/ha + Emerger 0.5 L/ha applied twice, and Anthem then Stomp 1.5 L/ha + Hurricane 0.05 L/ha applied twice at post-emergence. However, weed cover remained between 43% and 61% in these treatments, which is still at a level to cause yield reduction. This is because in the dry spring and summer weed control was challenging at the site, with little moisture for residual pre-emergence herbicides to work effectively, and it was also difficult to time the post-emergence due to the slow growth of the parsnips. By the time the crop reached the growth stage for the first application at two to three true leaves, the weeds had reached small rosette stage (10 cm across) and would have been harder to control. The site also had limited access to irrigation.

All pre-emergence treatments gave significant control of the weeds present for up to six weeks after application, and at this point reduced weed levels by at least 43% when compared to the untreated control (Table 7). With the exception of Flexidor 500 and AHDB9918, all the tank-mix partners added a further 20.5-28.8% weed control over Anthem applied alone.

The weed spectrum at the site included black bindweed, fat hen and groundsel with some volunteer oilseed rape, knotgrass, cranesbill, fumitory and volunteer potatoes.

Table 5. Mean percentage weed cover values (transformed) for Site 1. Post-emergence treatments applied 15th June and 28th June.

Trt. No.	Mean weed cover											
	28th May (3 weeks)		**14th Jun** (5 weeks)		**22nd Jun** (6 weeks)		**12th Jul** (9 weeks)		**27th Jul** (11 weeks)		**22nd Aug** (15 weeks)	
	Ang	**Back-trans**	**Ang**	**Back-trans**	**Ang**	**Back-trans**	**Ang**	**Back-trans**	**Ang**	**Back-trans**	**Ang**	**Back-trans**
Untreated*	17.0	8.5	29.8	24.7	41.5	44.0	73.8	92.3	75.2	93.5	71.3	89.7
Anthem	10.1	3.1	21.2	13.1	**31.5**	27.2	66.6	84.3	70.1	88.4	73.8	92.2
Anthem + Goltix	17.1	8.7	21.9	14.0	**24.6**	17.3	61.0	76.4	66.0	83.5	72.0	90.4
Anthem + aclonifen	9.7	2.9	14.8	6.5	**23.7**	16.2	65.0	82.1	70.5	88.9	75.2	93.5
Anthem + Hurricane SC	13.5	5.5	13.7	5.6	**22.4**	14.5	**54.8**	66.7	**60.1**	75.1	73.8	92.2
Anthem + chlorpropham	10.3	3.2	17.0	8.6	**25.0**	17.9	**59.1**	73.6	63.5	80.2	72.0	90.4
Anthem + Flexidor 500	9.3	2.6	19.7	11.4	**30.0**	25.0	69.2	87.4	72.0	90.4	77.1	95.0
Anthem + AHDB9998	11.9	4.3	19.2	10.8	**24.0**	16.5	**34.0**	31.2	**43.1**	46.7	66.8	84.5
Anthem + AHDB9918	14.3	6.1	17.4	9.0	**28.7**	23.1	59.7	74.6	67.1	84.9	67.5	85.3
Anthem + AHDB9999	11.8	4.2	14.2	6.0	**22.6**	14.8	**51.0**	60.4	**55.2**	67.4	70.3	88.7
Anthem + AHDB9917	15.3	7.0	20.7	12.5	**23.7**	16.2	**58.9**	73.3	63.7	80.3	73.4	91.8
Anthem, then (aclonifen) x2	16.7	8.3	29.4	24.1	32.2	28.3	**50.9**	60.1	**56.0**	68.8	78.7	96.1

Trt. No.	Mean weed cover											
	28th May (3 weeks)		14th Jun (5 weeks)		22nd Jun (6 weeks)		12th Jul (9 weeks)		27th Jul (11 weeks)		22nd Aug (15 weeks)	
	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans
Anthem, then (Hurricane SC) x2	17.6	9.1	28.4	22.6	**31.0**	26.4	66.0	83.5	68.1	86.1	73.8	92.2
Anthem, then (chlorpropham) x2	19.7	11.4	25.9	19.1	36.2	34.9	63.8	80.5	67.5	85.3	73.8	92.2
Anthem, then (AHDB9993) x2	17.7	9.3	24.8	17.6	**30.8**	26.2	63.5	80.1	67.8	85.8	71.4	89.8
Anthem, then (AHDB9981) x2	17.0	8.6	30.2	25.3	35.0	32.9	68.9	87.1	70.9	89.3	75.2	93.5
Anthem, then (Stomp Aqua + aclonifen) x2	14.9	6.6	26.5	19.9	**31.6**	27.5	**45.5**	50.9	**51.3**	61.0	78.7	96.1
Anthem, then (Stomp Aqua + Hurricane SC) x2	13.3	5.3	19.8	11.5	**25.1**	18.0	**56.3**	69.3	**61.3**	76.9	70.1	88.4
Anthem, then (Stomp Aqua + AHDB9993) x2	13.7	5.6	24.0	16.6	32.1	28.2	70.3	88.7	73.8	92.2	75.2	93.5
F prob. value		NS		NS		0.011		0.001		0.008		NS
d.f.		39		39		39		39		39		39
L.S.D.		7.618		11.20		9.622		14.31		13.51		6.303

() post-emergence treatment

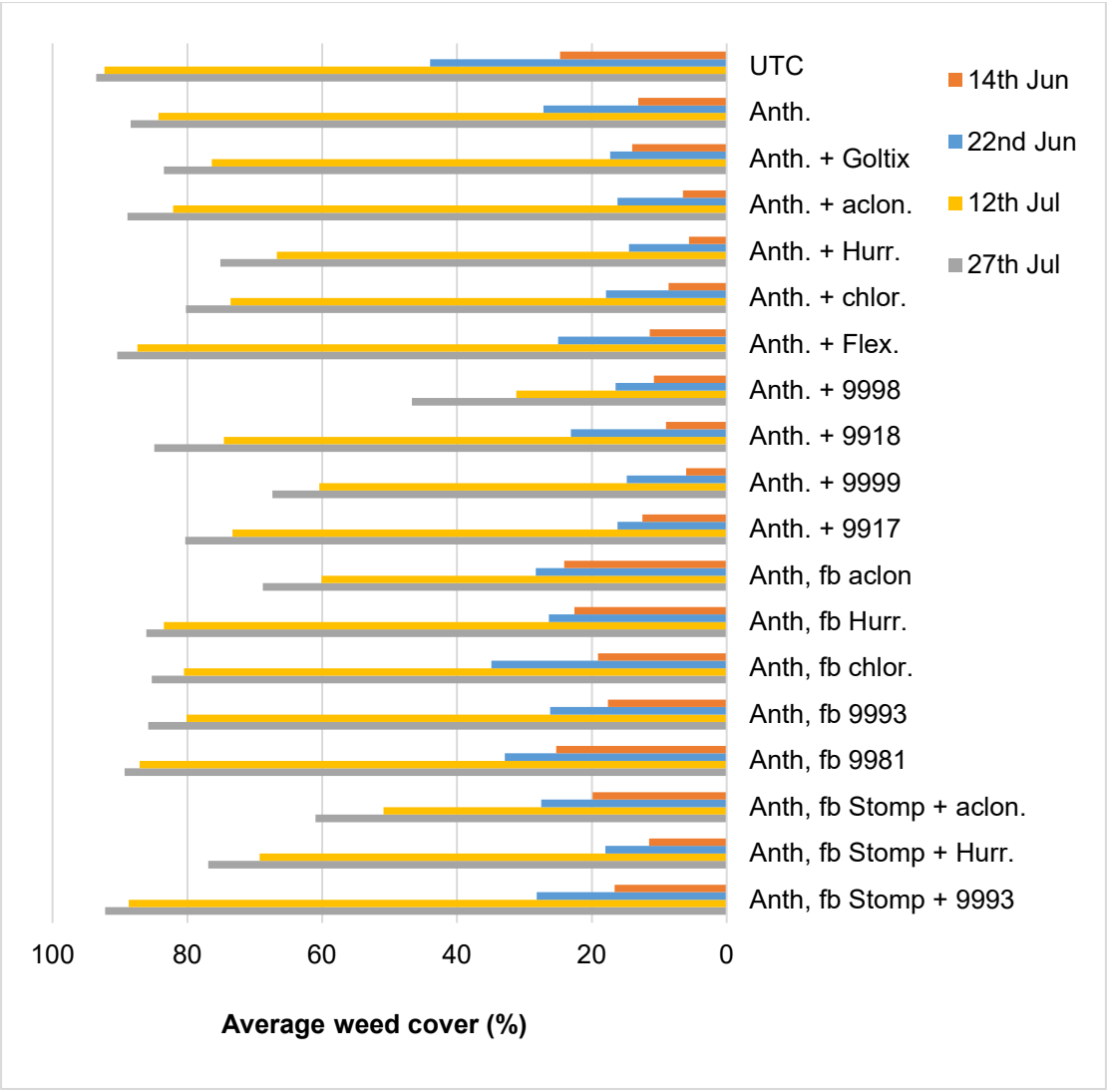


Figure 2. Mean weed cover (%) at six assessment dates throughout the trial at Site 1.

Site 2:
Weed cover results are presented in Table 6 and Figure 4. These figures were used to calculate the percent reduction in weed cover compared to the untreated control (using Abbotts formula), and these values are listed in Table 8.

Seven pre-emergence treatments and the standard Anthem 3.3 L/ha gave a significant reduction in the percentage of weed cover for up to 15 weeks after application. These were Anthem with the addition of the following in a tank-mix; Goltix, Emerger, chlorpropham, Flexidor 500, AHDB9998, AHDB9999, or AHDB9917. These treatments also gave 5.1-46.9% greater reduction in weed control than Anthem alone. Anthem 3.3 L/ha + chlorpropham 2.8 L/ha or the coded products AHDB9999 and AHDB9917 were the three best performing pre-emergence products in the trial.

All of the post-emergence treatments gave a significant reduction in weed cover for up to seven weeks after the final application, and gave 59-81 % reduction in weed cover compared to the untreated control (Table 8). The crop was irrigated and further forward than the Site 1 parsnip crop and therefore the parsnips reached the target application timing of two to three true leaves before the weeds got bigger than three to four true leaves (5 cm diameter); the weeds were smaller and greater efficacy was gained from the better timing of application with respect to weed growth stage.

The weed spectrum at the site included mainly redshank, black bindweed and groundsel, with a little fat hen and fumitory. Weed levels fell after 1st August assessment, which would be due to natural senescence of the groundsel.

Table 6. Mean percentage weed cover values (transformed) for Site 2. Post-emergence treatments applied 29th June and 14th July.

Trt. No.	Mean weed cover									
	29th June (6 weeks)		**13th July** (8 weeks)		**1st Aug** (11 weeks)		**17th Aug** (13 weeks)		**30th Aug** (15 weeks)	
	Ang	**Back-trans**	**Ang**	**Back-trans**	**Ang**	**Back-trans**	**Ang**	**Back-trans**	**Ang**	**Back-trans**
Untreated*	51.9	61.96	57.6	71.3	87.5	99.81	79.3	96.58	75.3	93.58
Anthem	**10.9**	3.62	35.3	33.36	**53.4**	64.38	**50.1**	58.91	**43.0**	46.5
Anthem + Goltix	**9.2**	2.54	38.7	39.16	**54.7**	66.58	**41.1**	43.16	**37.2**	36.58
Anthem + Emerger	**7.9**	1.92	46.1	51.83	68.3	86.31	**54.4**	66.10	**40.5**	42.21
Anthem + Hurricane SC	**14.7**	6.49	38.6	38.84	**73.1**	91.56	66.3	83.81	63.1	79.46
Anthem + chlorpropham	**5.9**	1.08	27.9	21.84	**48.0**	55.23	**41.1**	43.25	**22.8**	14.97
Anthem + Flexidor 500	**8.7**	2.31	46.0	51.67	**61.4**	77.13	**47.9**	55.00	**40.8**	42.68
Anthem + AHDB9998	**7.4**	1.65	28.5	22.83	**42.1**	44.94	**46.3**	52.29	**38.0**	37.92
Anthem + AHDB9918	**14.5**	6.28	40.0	41.32	**67.9**	85.82	**60.5**	75.76	57.4	71.00
Anthem + AHDB9999	**5.4**	0.89	33.0	29.72	**57.0**	70.33	**43.1**	46.65	**34.8**	32.64
Anthem + AHDB9917	**8.2**	2.00	46.0	51.67	**57.7**	71.51	**43.9**	48.04	**34.8**	32.55
Anthem, then (Emerger) x2	**11.3**	3.86	42.0	44.82	**42.2**	45.03	**26.0**	19.24	**20.6**	12.40
Anthem, then (Hurricane SC) x2	**7.6**	1.74	30.7	26.07	**38.2**	38.27	**43.1**	46.63	**38.1**	38.05
Anthem, then (chlorpropham) x2	**8.9**	2.44	46.0	51.78	**47.3**	53.94	**47.6**	54.51	**26.6**	20.05
Anthem, then (AHDB9993) x2	**9.4**	2.65	29.4	24.14	**49.1**	57.20	**48.2**	55.65	**36.9**	36.10
Anthem, then (AHDB9981) x2	**9.9**	3.00	46.0	51.67	**59.1**	73.58	**41.1**	43.24	**33.1**	29.90
Anthem, then (Stomp Aqua + Emerger) x2	**11.9**	4.28	52.8	63.40	**54.0**	65.38	**36.1**	34.65	**24.9**	17.74
Anthem, then (Stomp Aqua + Hurricane SC) x2	**7.9**	1.92	27.5	21.35	**48.9**	56.72	**39.5**	40.45	**28.4**	22.59
Anthem, then (Stomp Aqua + AHDB9993) x2	**11.4**	3.89	46.9	53.39	**56.7**	69.91	**45.9**	51.52	**29.9**	24.92
F prob. value	<0.001		NS		<0.001		<0.001		<0.001	
d.f.	39		39		39		39		39	
L.S.D.	9.495		22.20		19.41		17.66		18.36	

() post-emergence treatment

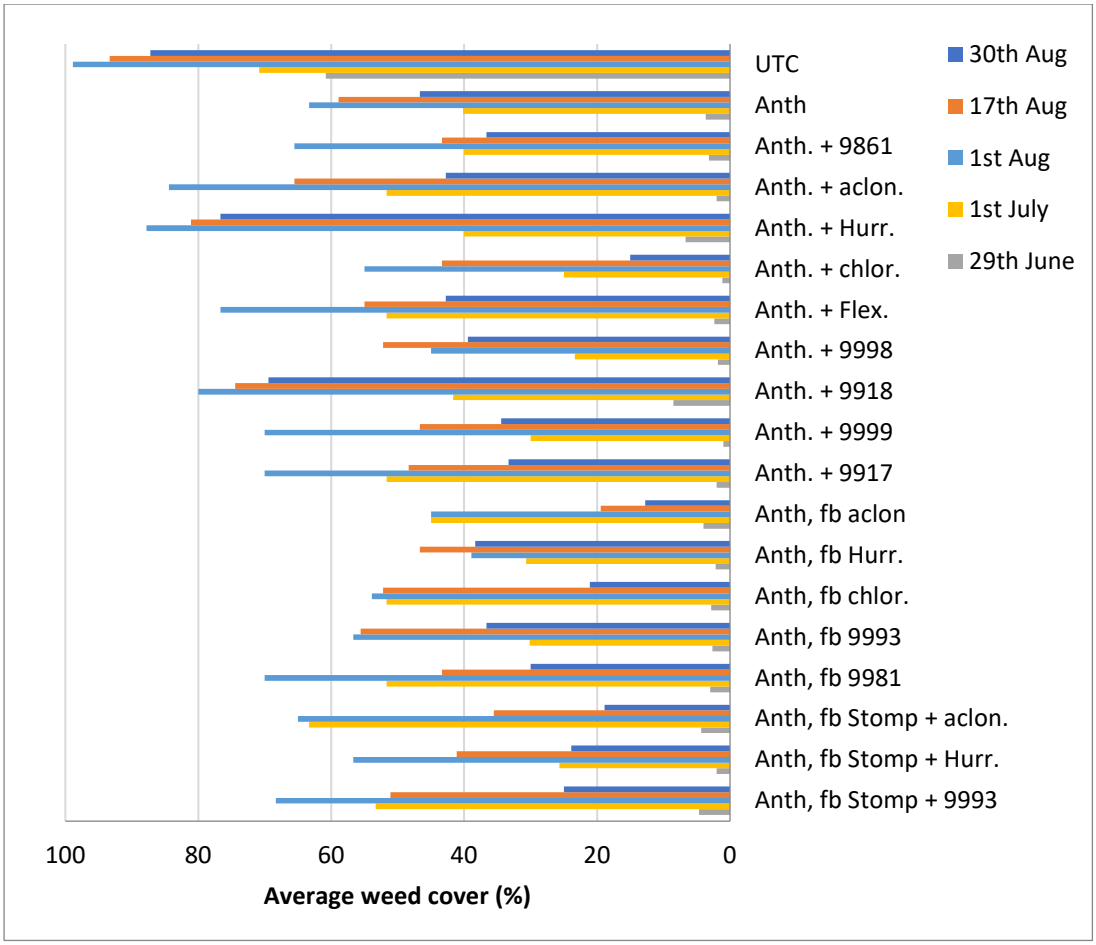


Figure 4. Mean weed cover (%) at six, eight, eleven, thirteen and fifteen weeks after treatment application to Site 2.

Weed control - % weed reduction – Abbotts formula

Table 7. Percentage reduction in weed cover compared to the untreated control at six assessment dates throughout the trial at Site 1 – values highlighted in red show an increase in weed cover.

Treatment	Weed cover reduction (%)					
	28th May (3 weeks)	14th Jun (5 weeks)	22nd Jun (6 weeks)	12th Jul (9 weeks)	27th Jul (11 weeks)	22nd Aug (15 weeks)
Anthem	64.1	47.1	38.1	8.7	5.4	-2.8
Anthem + Goltix	-1.7	43.5	60.6	17.1	10.7	-0.7
Anthem + Emerger	66.4	73.7	63.2	11.0	4.9	-4.2
Anthem + Hurricane SC	35.7	77.3	67.1	27.7	19.6	-2.8
Anthem + chlorpropham	62.1	65.3	59.4	20.3	14.2	-0.7
Anthem + Flexidor 500	69.5	53.9	43.1	5.2	3.3	-5.9
Anthem + AHDB9998	49.7	56.1	62.5	66.2	50.1	5.8

Treatment	Weed cover reduction (%)					
	28th May (3 weeks)	14th Jun (5 weeks)	22nd Jun (6 weeks)	12th Jul (9 weeks)	27th Jul (11 weeks)	22nd Aug (15 weeks)
Anthem + AHDB9918	28.3	63.6	47.4	19.2	9.2	4.9
Anthem + AHDB9999	51.2	75.7	66.4	34.5	27.9	1.2
Anthem + AHDB9917	18.0	49.5	63.1	20.6	14.1	-2.3
Anthem, then (Emerger) x2	2.8	2.4	35.6	34.8	26.4	-7.1
Anthem, then (Hurricane SC) x2	-7.3	8.4	39.9	9.5	7.9	-2.8
Anthem, then (chlorpropham) x2	-33.9	22.7	20.5	12.8	8.7	-2.8
Anthem, then (AHDB9993) x2	-8.8	28.9	40.4	13.2	8.3	-0.1
Anthem, then (AHDB9981) x2	-0.6	-2.4	25.2	5.6	4.5	-4.2
Anthem, then (Stomp Aqua + Emerger) x2	22.8	19.4	37.4	44.8	34.8	-7.1
Anthem, then (Stomp Aqua + Hurricane SC) x2	37.7	53.4	59.0	24.9	17.7	1.5
Anthem, then (Stomp Aqua + AHDB9993) x2	34.4	32.8	35.8	3.9	1.4	-4.2

() post-emergence treatment

Table 8. Percentage reduction in weed cover compared to the untreated control at six, eight, eleven, thirteen and fifteen weeks after treatment application to Site 2.

Treatment	Weed cover reduction (%)				
	29th June (6 weeks)	13th July (8 weeks)	1st Aug (11 weeks)	17th Aug (13 weeks)	30th Aug (15 weeks)
Anthem	94.17	53.21	35.50	39.00	50.31
Anthem + Goltix	95.90	45.08	33.29	55.31	60.91
Anthem + Emerger	96.91	27.31	13.53	31.56	54.89
Anthem + Hurricane SC	89.53	45.53	8.27	13.22	15.09
Anthem + chlorpropham	98.25	69.37	44.66	55.22	84.00
Anthem + Flexidor 500	96.27	27.53	22.72	43.05	54.39
Anthem + AHDB9998	97.33	67.98	54.97	45.86	59.48
Anthem + AHDB9918	89.86	42.05	14.02	21.56	24.13

Treatment	Weed cover reduction (%)				
	29th June (6 weeks)	**13th July** (8 weeks)	**1st Aug** (11 weeks)	**17th Aug** (13 weeks)	**30th Aug** (15 weeks)
Anthem + AHDB9999	98.56	58.32	29.54	51.70	65.12
Anthem + AHDB9917	96.77	27.53	28.35	50.26	65.22
Anthem, then (Emerger) x2	93.78	37.14	54.88	80.08	86.75
Anthem, then (Hurricane SC) x2	97.20	63.44	61.66	51.72	59.34
Anthem, then (chlorpropham) x2	96.07	27.38	45.96	43.56	78.57
Anthem, then (AHDB9993) x2	95.73	66.14	42.69	42.38	61.42
Anthem, then (AHDB9981) x2	95.16	27.53	26.28	55.23	68.05
Anthem, then (Stomp Aqua + Emerger) x2	93.09	11.08	34.50	64.12	81.04
Anthem, then (Stomp Aqua + Hurricane SC) x2	96.91	70.06	43.17	58.12	75.86
Anthem, then (Stomp Aqua + AHDB9993) x2	93.71	25.12	29.96	46.66	73.37

() post-emergence treatment

Fanging – Site 2 only

Due to missing values in the untreated plots—which could not be included as the parsnips were very small and deformed due to weed competition, rather than treatment effect—the trial design became unbalanced and was analysed by regression instead of ANOVA (using Genstat). There were no significant differences and no more than a mean of 1.3% fanged parsnips in the highest scoring treatment.

Discussion

The weed spectrums at both sites were similar, but the proportions of the main weed species at each site were different. At Site 1, black bindweed and fat hen were dominant, with a little groundsel and some volunteer oilseed rape, knotgrass, cranesbill, fumitory and volunteer potatoes. At Site 2, there was mainly redshank and black bindweed with a greater amount of groundsel than Site 1, with a little fat hen and fumitory.

Although there were significant reductions in percentage weed cover at each site, these differences in species proportions highlighted some differences in product performance. For example, Anthem 3.3 L/ha + Hurricane SC 0.1 L/ha gave a significant reduction in percentage weed cover at Site 1, but was not one of the best performing products at Site 2. There was a higher proportion of groundsel at Site 2 and Hurricane SC has a weakness on groundsel control, accounting for the difference. Therefore, while a number of products gave a significant reduction in percentage weed cover compared to the untreated control, consideration needs to be given to target the weed species present at the site to gain the greatest efficacy, as many of the novel products in the trial have narrower weed spectrums.

The lower persistence of efficacy at **Site 1** due to the restricted irrigation at the site in a dry spring also shows the importance of moisture for pre-emergence residual herbicides to work to their full potential. At this site, only three pre-emergence treatments gave statistically significant reductions in weed cover at eleven weeks after application at the end of July. These were; Anthem 3.3 L/ha + Hurricane 0.1 L/ha, Anthem + AHDB9998 and Anthem + AHDB9999. Despite a significant reduction, weed cover was still between 43% and 61% in these treatments, which would still be at a level to cause yield reduction.

However, at earlier assessments all pre-emergence treatments gave significant control of the weeds present for up to six weeks after application, and at this point reduced weed levels by at least 43% when compared to the untreated control. With the exception of Flexidor 500 and AHDB9918, all the tank-mix partners added a further 20.5-28.8% weed control over Anthem applied alone. Therefore Emerger, Hurricane SC, chlorpropham, AHDB9998, AHDB9999 and AHDB9917 would be useful alternative tank-mix partners to Goltix (metamitron).

At **Site 2**, seven pre-emergence treatments and the standard Anthem 3.3 L/ha gave a significant reduction in the percentage of weed cover for up to fifteen weeks after application. These were Anthem with the addition of the following in a tank-mix; Goltix, Emerger, chlorpropham, Flexidor 500, AHDB9998, AHDB9999, or AHDB9917. These treatments also gave 5.1-46.9% greater reduction in weed control than Anthem alone. Anthem 3.3 L/ha + chlorpropham 2.8 L/ha or the coded products AHDB9999 and AHDB9917 were the three best performing pre-emergence products in this trial. This site had access to irrigation and therefore the residual herbicides were able to work more effectively.

The pre-emergence treatments still left a moderate percentage of weed, even after significantly reducing weed levels. As no products are currently authorised for post-emergence use in parsnips, options are urgently required for approval. While alternative approaches such as inter-row weeding are available, these are not always appropriate and herbicides are still required. Anthem 3.3 L/ha then Emerger 0.5 L/ha applied twice, Anthem then Stomp 1.5 L/ha + Emerger 0.5 L/ha applied twice and Anthem then Stomp 1.5 L/ha + Hurricane 0.05 L/ha gave significant control at both sites reducing weed levels by up to 25-34% at Site 1, and 75-86% at Site 2. The lower efficacy at **Site 1** was because it was difficult to time the post-emergence application due to the slow growth of the parsnips and by the time the crop reached the growth stage for the 1st application at two to three true leaves, the weeds had reached small rosette stage (10 cm across) and were harder to control.

Assessment of phytotoxicity at both of the trial sites was difficult after mid-July due to the high weed levels in the plots, and confounding effects of stunting caused by this competition. However, there was no crop loss seen in the assessments completed before this point. The main crop effects seen were chlorosis, scorch or stunting, all of which would likely be transient, and were not noted at any of the later efficacy assessments.

In the pre-emergence treatments; at the final assessment in July there were no effects seen on the crop at Site 1, and the scores below eight at Site 2 were from stunting caused by increased weed levels in those plots rather than effects from treatments. The only treatment to show a moderate phytotoxicity score at Site 1 was Anthem 3.3 L/ha + Hurricane SC 0.1 L/ha where interveinal chlorosis was seen at three weeks after the pre-emergence application. This was transient, and the crop had grown through the effect by the next assessment two weeks' later.

At four weeks after the final post-emergence application at Site 1, only plots treated with AHDB9981 still showed a crop effect—yellow clouding of leaves. However, this would be likely to be transient, and crop vigour was unaffected. There were also transient crop effects from Emerger (aclonifen) and Hurricane SC (diflufenican) which occurred after the first post-emergence application and persisted until two weeks after the second post-emergence application. Emerger gave a yellow spotting on the leaves, and Hurricane gave interveinal bleaching or chlorosis and stunting. Only slight traces of these effects were present at a month after the final application, and new growth was unaffected.

There were no significant reductions in plant population at Site 1 at either assessment. At Site 2, there were no significant differences between the untreated and treatments at the first assessment, and no change in plant population after post-ems were applied at the second assessment. At Site 1, the significant differences at the second assessment were caused by a reduction in the plant population of the untreated due to crop loss from weed competition, and therefore the results of this assessment are confounded.

Emerger is authorised under EAMU 1601/19 for pre-emergence use on parsnip and is a useful addition to programmes which growers can use immediately, but it has only been tested in tank-mix with pendimethalin, and other mixes would need to be tested carefully before use on a large area of crop. A post-emergence EAMU authorisation for Emerger would also be very useful and it was one of the best performing products at this timing.

Authorisations for pre-emergence use of Hurricane SC, chlorpropham, AHDB9998, AHDB9999 and AHDB9917 would improve weed control for parsnip growers, while AHDB9981 and Hurricane SC would be useful post-emergence products to pursue for EAMUs.

Conclusions

- At pre-emergence, products Emerger 1.5 L/ha, Hurricane SC 0.1 L/ha, chlorpropham 2.8 L/ha, AHDB9998, AHDB9999 and AHDB9917 gave a significant reduction in percentage weed cover for up to six weeks after application

- AHDB9999 was one of the best performing pre-emergence products in both trials, while Hurricane SC 0.1 L/ha and AHDB9998 performed well at Site 1, and chlorpropham and AHDB9917 performed well at Site 2.

- This indicates that it is important to select the appropriate herbicide for the anticipated target weed spectrum to gain the best efficacy.

- At post-emergence, treatments Emerger 0.5 L/ha and Anthem1.5 L/ha + Emerger 0.5 L/ha and Anthem 1.5 L/ha + Hurricane SC 0.05 L/ha gave a significant reduction in percentage weed cover for up to three weeks after application at Site 1, and seven weeks after application at Site 2.

- There were no reductions in plant population, and no persistent foliar effects. However, there were some transient crop effects after the post-emergence applications from Emerger (aclonifen), Hurricane SC (diflufenican) and AHDB9981. This occurred after the first post-emergence application and persisted until two weeks after the second post-emergence application. Emerger gave a yellow spotting on the leaves, Hurricane gave interveinal bleaching or chlorosis and stunting, and AHDB9981 gave yellow areas of the leaves.

Acknowledgements

AHDB for funding the work, and also the crop protection companies for their financial contributions and provision of 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 Philip Lilley of T Hammond farms, Jason Ambrose of Tompsett Burgess group, Pete Saunders, of Alan Bartlett & Sons, and Ian Holmes, of Strawson Ltd.

Appendix

a. Crop diary – events related to growing crop

Site 1:

Crop	**Cultivar**	**Planting date**	**Row width** (m)
Parsnip	Javelin	08/05/2018	

Previous cropping

Year	**Crop**
2018	
2017	
2016	
2015	

Cultivations

Date	**Description**	**Depth** (cm)

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

Date	**Product**	**Rate** (kg/ha)

Pesticides applied to trial area

Date	**Product**	**Rate** (L/ha)

Details of irrigation regime

Date	**Type, rate and duration**	**Amount applied** (mm)

Site 2:

Crop	**Cultivar**	**Drilling date**	**Row width** (m)
Parsnip	Javelin		

Previous cropping

Year	**Crop**
2018	
2017	
2016	
2015	

Cultivations

Date	**Description**	**Depth** (cm)

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

Date	**Product**	**Rate** (kg/ha)

Pesticides applied to trial area

Date	**Product**	**Rate** (L/ha)

Details of irrigation regime

Date	**Type, rate and duration**	**Amount applied** (mm)

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

Site 1:

Date	**Event**
08/05/2018	Crop drilled.
09/05/2018	Pre-emergence treatments applied to main plots.
18/05/2018	Pre-emergence treatments applied to split plots.
28/05/2018	Trial assessment – weed cover and phytotoxicity.
06/06/2018	Trial assessment – crop population count.
14/06/2018	Trial assessment – weed cover and phytotoxicity.
15/06/2018	First post-emergence treatments applied to main plots.
22/06/2018	Trial assessment – weed cover, phytotoxicity, and crop population count.
28/06/2018	Second post-emergence treatments applied to main plots.
12/07/2018	Trial assessment – weed cover and phytotoxicity.
27/07/2018	Trial assessment – weed cover and phytotoxicity.
22/08/2018	Trial assessment – weed cover and phytotoxicity.

Site 2:

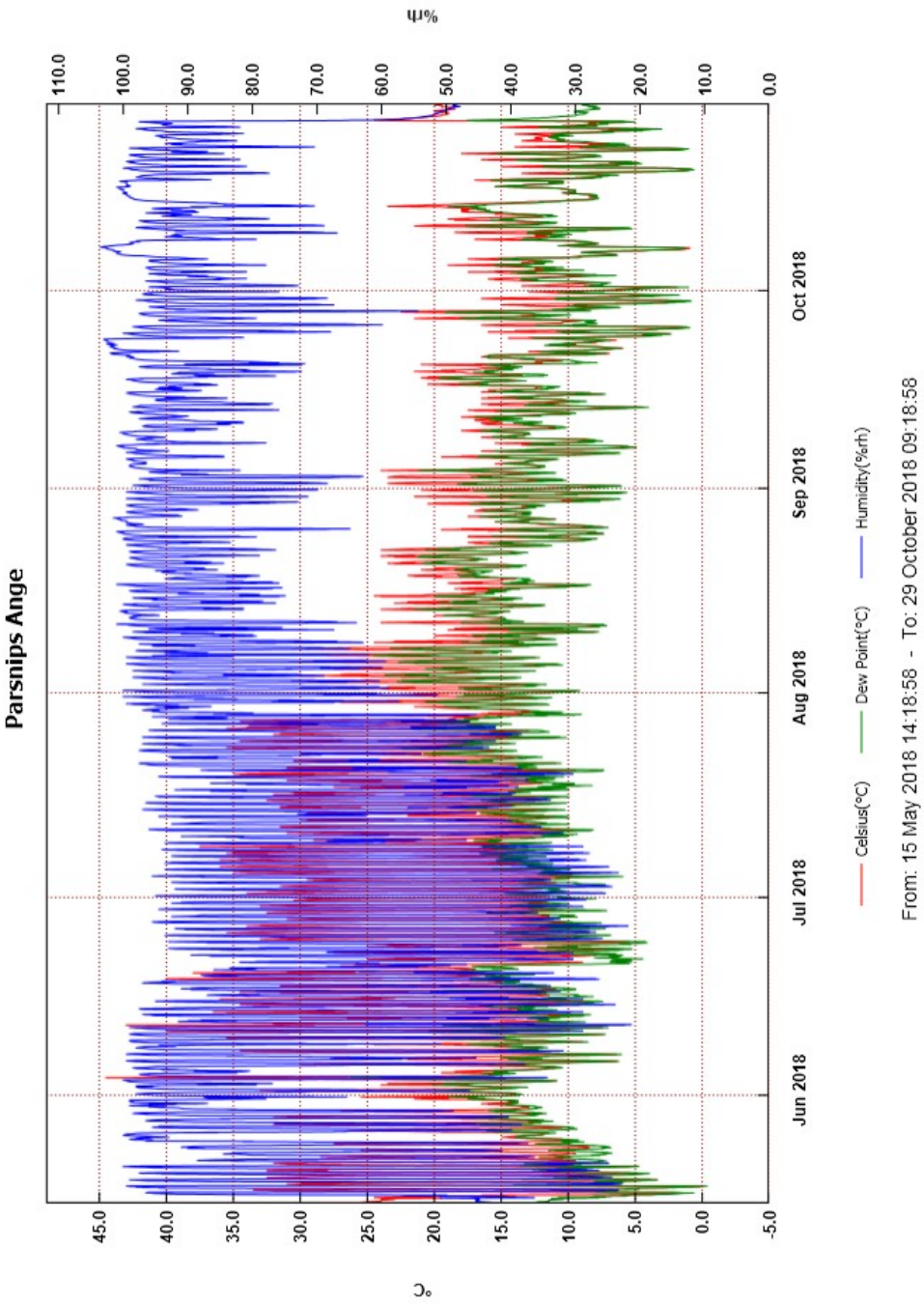
Date	Event
13/05/2018	Crop drilled.
19/05/2018	Pre-emergence treatments applied to main plots.
31/05/2018	Pre-emergence treatments applied to split plots.
20/06/2018	Trial assessment – weed cover, phytotoxicity and plant population count
29/06/2018	Trial assessment – weed cover and phytotoxicity First post-emergence treatments applied to plots
14/07/2018	Trial assessment – weed cover and phytotoxicity Second post-emergence treatments applied to plots
02/08/2018	Trial assessment – weed cover and plant population count
30/08/2018	Trial assessment – weed cover
25/08/2018	100 roots dug and harvested per plot for fanging assessment
26/10/2018	Trial assessment – fanging of roots

c. Climatological data during study period from each site.
Site 1 - Norfolk

Date	Temperature °C (minimum)	Temperature °C (maximum)	Rainfall* (mm)
08/05/2018	16.0	30.0	
09/05/2018	8.0	24.0	
10/05/2018	9.5	19.5	
11/05/2018	7.5	20.5	
12/05/2018	8.5	19.0	
13/05/2018	9.5	18.0	
14/05/2018	6.5	18.5	
15/05/2018	6.0	22.5	
16/05/2018	8.0	14.0	
17/05/2018	4.5	18.0	
18/05/2018	3.5	20.0	
19/05/2018	3.0	23.5	
20/05/2018	8.0	24.0	
21/05/2018	7.0	27.0	
22/05/2018	8.0	21.5	
23/05/2018	9.5	20.5	
24/05/2018	10.5	27.0	
25/05/2018	12.0	20.0	
26/05/2018	13.5	25.0	
27/05/2018	12.5	27.5	
28/05/2018	12.5	27.5	
29/05/2018	12.0	22.0	
30/05/2018	12.0	18.5	
31/05/2018	13.5	24.5	
01/06/2018	15.5	26.0	
02/06/2018	17.0	27.0	
03/06/2018	13.0	26.5	
04/06/2018	13.0	17.5	
05/06/2018	9.5	19.0	
06/06/2018	6.5	24.0	
07/06/2018	9.0	22.5	
08/06/2018	9.5	22.5	
09/06/2018	11.5	20.0	
10/06/2018	12.0	25.0	
11/06/2018	7.0	27.5	
12/06/2018	10.5	19.5	
13/06/2018	7.5	25.0	
14/06/2018	13.0	25.5	
15/06/2018	9.5	25.0	
16/06/2018	13.0	23.0	
17/06/2018	11.0	21.0	
18/06/2018	15.0	27.5	
19/06/2018	17.5	26.5	
20/06/2018	15.5	27.5	
21/06/2018	8.5	21.5	
22/06/2018	7.0	22.0	
23/06/2018	9.5	26.0	
24/06/2018	9.0	27.0	
25/06/2018	11.5	30.0	
26/06/2018	9.5	29.5	
27/06/2018	12.5	28.0	
28/06/2018	10.0	28.0	
29/06/2018	11.5	28.0	
30/06/2018	12.5	29.0	
01/07/2018	11.0	30.0	

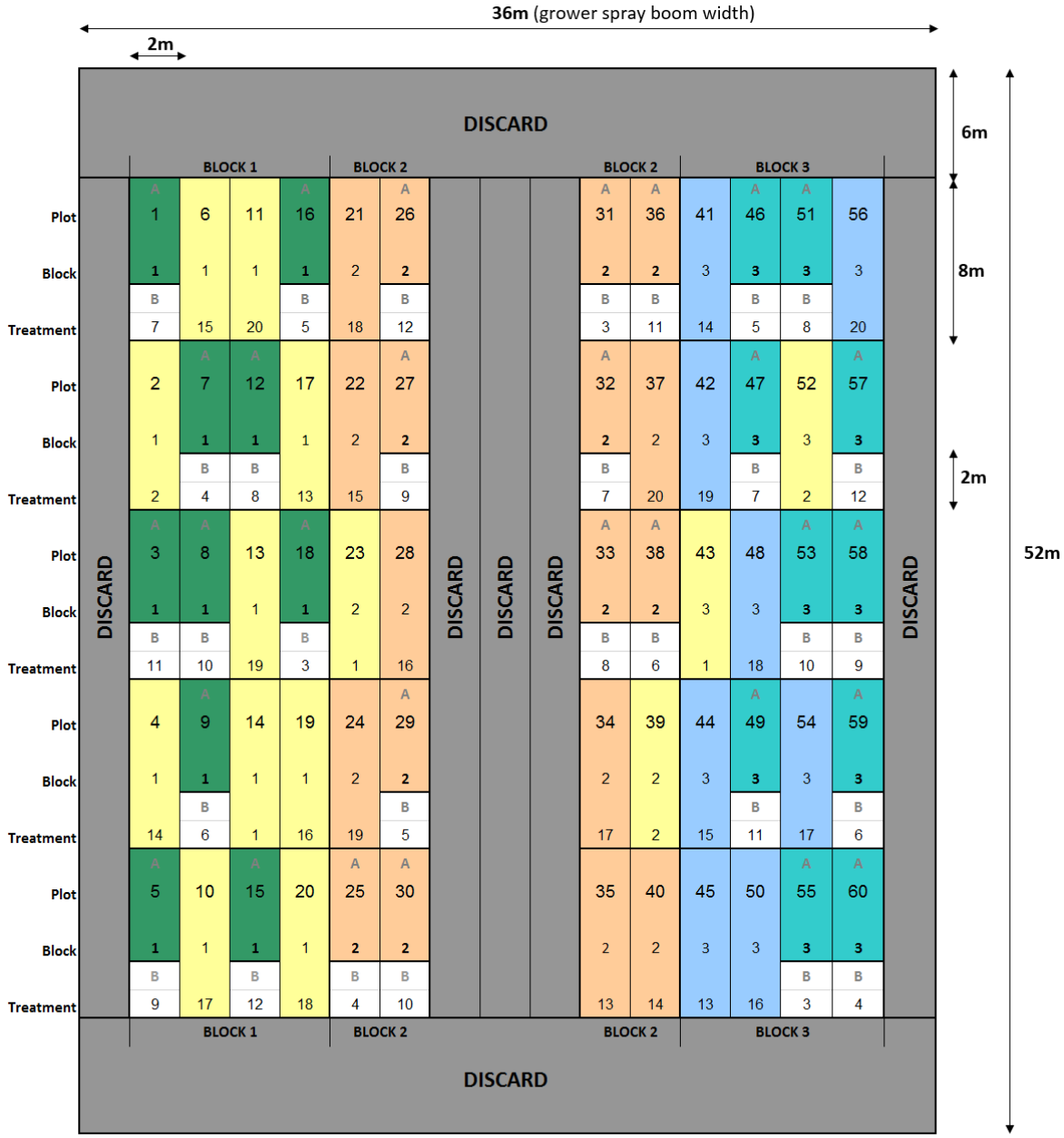
02/07/2018	11.5	29.0	
03/07/2018	9.5	26.5	
04/07/2018	10.5	27.5	
05/07/2018	14.5	30.5	
06/07/2018	14.5	28.0	
07/07/2018	16.0	31.0	
08/07/2018	13.0	29.5	
09/07/2018	16.0	29.0	
10/07/2018	13.5	21.0	
11/07/2018	13.5	22.0	
12/07/2018	12.5	23.0	
13/07/2018	10.5	27.5	
14/07/2018	12.5	31.0	
15/07/2018	14.0	34.5	
16/07/2018	14.0	32.0	
17/07/2018	15.5	25.5	
18/07/2018	14.5	29.5	
19/07/2018	15.5	30.5	
20/07/2018	14.5	30.0	
21/07/2018	16.0	31.0	
22/07/2018	15.0	30.0	
23/07/2018	16.0	34.5	
24/07/2018	16.5	33.0	
25/07/2018	16.0	34.0	
26/07/2018	17.5	36.0	
27/07/2018	20.0	32.0	
28/07/2018	16.0	23.5	
29/07/2018	14.5	20.0	
30/07/2018	16.5	24.0	
31/07/2018	16.0	26.0	
01/08/2018	14.0	29.0	
02/08/2018	15.0	32.5	
03/08/2018	17.5	33.0	
04/08/2018	17.5	27.0	
05/08/2018	15.0	33.0	
06/08/2018	17.0	35.0	
07/08/2018	17.0	33.0	
08/08/2018	17.5	26.5	
09/08/2018	14.0	18.0	
10/08/2018	11.0	17.0	
11/08/2018	9.5	22.5	
12/08/2018	16.0	20.0	
13/08/2018	16.0	21.0	
14/08/2018	14.0	23.0	
15/08/2018	14.5	24.5	
16/08/2018	14.5	18.5	
17/08/2018	11.0	19.5	
18/08/2018	14.5	21.5	
19/08/2018	16.5	22.5	
20/08/2018	16.5	24.0	
21/08/2018	16.5	26.5	
22/08/2018	14.5	24.0	

Site 2 – Notts


Parsnips Ange
%rh
°C
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
Jun 2018
Jul 2018
Aug 2018
Sep 2018
Oct 2018
Celsius(°C)
Dew Point(°C)
Humidity(%rh)
From: 15 May 2018 14:18:58 - To: 29 October 2018 09:18:58

d. Trial design

Site 1:



Site 2:

ADAS GT PARSNIPS 2018 -ARNOLD

PLOT SIZE= 8 x 1.85m

SPLIT PLOTS A = 6 x 1.85m

B = 2 x 1.85m

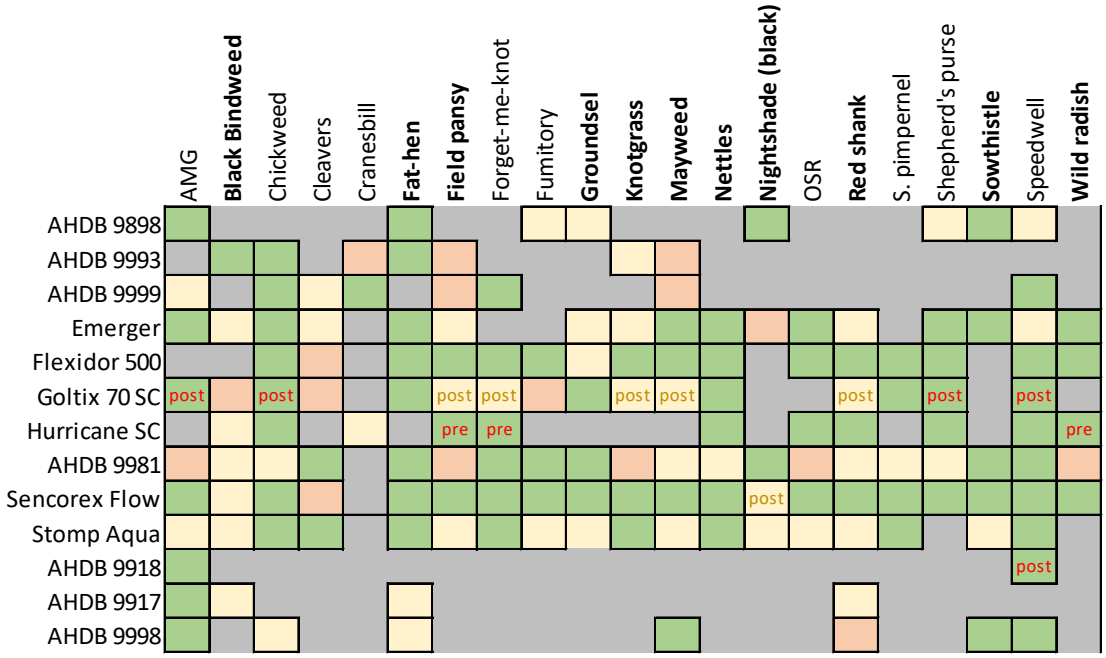
SPRAYER 24m width

SPRAYER 24m width

	1	2	3	4	5	6	7	8	9	10		
spare	10	16	12	5	18	20	1	4	15	13		spare
	11	12	13	14	15	16	17	18	19	20		
spare	6	14	3	17	8	19	7	11	9	2		spare
	21	22	23	24	25	26	27	28	29	30		
spare	5	15	18	14	2	1	6	19	17	3		spare
	31	32	33	34	35	36	37	38	39	40		
spare	9	10	13	12	8	7	11	16	4	20		spare
	41	42	43	44	45	46	47	48	49	50		
spare	15	5	20	7	14	19	17	9	13	18		spare
	51	52	53	54	55	56	57	58	59	60		
spare	2	1	8	11	3	16	6	12	10	4		spare

GATE WAY

e. Matrix of weed species controlled by the products in the trial



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