SCEPTREPLUS

Final Trial Report

Trial code:	2019.SP01
Title:	AHDB SCEPTREplus parsnip herbicide screen
Crop	Group: Field vegetables – Parsnip (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:	1st April 2019 – 31st March 2020
Report date:	29th February 2020
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

New products are required to supplement the limited list of actives currently available to parsnip growers as gaps in weed control still remain after the loss of linuron. This trial focused on finding safe and effective options for post-emergence weed control and understanding how they are best included in current programmes.

While extensions of authorisation for use of prosulfocarb (June 2013), metamitron (December 2014) and aclonifen (April 2019) have been issued, the two most recently approved products are for pre-emergence application only, so identifying alternative weed control options for post-emergence use continues to be a priority. This trial examined the crop safety and efficacy of these actives, applied post-emergence in various tank-mixes. Two novel products were also evaluated—these were carried forward from work in 2018.

Method

Two separate trials were sited in commercial parsnip fields on sandy soils; one in Suffolk (Site 1) and one in Nottinghamshire (Site 2). A randomised block design was used for the trial layout, with three replicates of eight treatments, including an untreated control and a grower standard treatment. There were twenty-four plots in total at each site, with plots measuring 2 m x 6 m.

Site 1

Treatments were applied at four timings. The first were applied on 30th April 2019 (BBCH00-03), with subsequent applications on 15th May, 31st May (BBCH11-12), and 28th June (BBCH14).

Site 2

Treatments were applied at four timings. The first were applied on 12th May (BBCH00-03), with subsequent application on 20th June (BBCH13), 2nd July (BBCH14), and 12th July (BBCH14).

All treatments were applied with a 2m boom, using a knapsack sprayer at 200 L/ha water volume.

The plots were assessed on five occasions, focusing on weed cover and species presence, and crop phytotoxicity (i.e. treatment safety). Assessments were carried out at two of the treatment application timings, and at approximately two, four and eight weeks after the Timing D application.

Results and discussion

Of the treatments assessed in these trials, five appeared crop safe (**Table 1**) and gave statistically significant weed control (**Table 2**)—**Anthem, then AHDB9981 (low rate)**; **Anthem, then AHDB9981 (high rate)**; **Anthem, then AHDB9981 + Emerger**; **Anthem, then AHDB9981 + AHDB9997**; and **Anthem, then AHDB9981 + AHDB9997 + Emerger**. By the conclusion of the trial, eight weeks after the final treatment application, all these treatments offered a significant reduction in weed cover compared to the untreated control, with none exhibiting any notable phytotoxic symptoms.

Regarding the treatments' effects on plant population, there were no significant differences between the treatments and the untreated crop at the first assessment at Site 1. However, at this site's second assessment, the application of **Defy + Goltix** did show a significant population reduction (no differences observed for other treatments). There were no significant reductions in plant population at Site 2 at either assessment. This can be attributed to the treatment application delay leading to the crop's larger size—and consequent increased resilience—at Site 2.

These trials also highlighted the significance of application timing in treatment efficacy. At Site 1, there was a heavy weed burden, with a mean weed cover of 100% two weeks after the final treatment application. However, all treatments appeared to offer significant and persistent

control. While Site 2 had fewer weeds—with a mean weed cover of 9.1% two weeks after the final treatment application—but there were (almost) no significant treatment effects. With weather causing a delay in the Site 2 treatment applications, the Timing B application was made 39 days after the previous treatment application, whereas the spray interval was only 15 days at Site 1. This could explain the apparent differences in treatment efficacy between the two sites. Due to the delay in application timing, the Site 2 weeds and crop were larger when they were treated, thus treatments were less effective at this site (relative to the potential weed cover, as seen in the untreated plots).

The differences in each site's weed spectrum is also significant. At Site 1, there was considerably more fat hen than any other weed species. Mayweed, annual meadow grass and groundsel were also common, though the latter had naturally senesced before the final assessment. At Site 2, volunteer wheat was the most common weed, followed by groundsel and volunteer potatoes. This is noteworthy as **Defy**, **Hurricane SC** and **Emerger** are currently authorised for use in wheat and/or potato crops, hence their inherent inefficacy at Site 2 given the weed spectrum.

Emerger is authorised under EAMU 1601/19 for pre-emergence use on parsnip. A post-emergence EAMU authorisation for this product would also be very useful as its performance was promising in this trial.

The use of **AHDB9981** and **Hurricane SC** on parsnips is not currently approved, though these products also showed promise in this trial. **AHDB9981** was both screened at different application rates and tested in various tank-mix combinations, and by the conclusion of the trials showed lasting efficacy without any persistent phytotoxic effects. Similarly, **Hurricane SC**—which was trialed as a tank-mix partner—contributed to treatments which appeared effective and crop safe by the final assessment. These products would be valuable additions to parsnip growers' weed control options, and pursual of EAMUs would be useful.

Table 1. Mean phytotoxicity scores at Timing D, and two and eight weeks (nine weeks for Site 2) after Timing D treatment application.

Treatment	Mean crop damage scores (0-10)					
	Site 1			Site 2		
	(28/06/19) **Timing D**	**+ 2 weeks**	**+ 8 weeks**	(12/07/19) **Timing D**	**+ 2 weeks**	**+ 9 weeks**
Untreated	0.0	0.0	0.0	0.0	0.0	0.0
Anthem, then **Defy** + **Goltix**	***5.0**	***5.0**	***4.0**	***8.0**	***5.7**	0.3
Anthem, then **Defy** + **Emerger**	0.3	0.0	***3.0**	0.7	0.0	0.3
Anthem, then **AHDB9981** (x2) (low rate)	1.0	0.3	1.0	1.7	0.0	0.0
Anthem, then **AHDB9981** (x2) (high rate)	1.7	1.7	1.0	2.0	0.0	0.0
Anthem, then **AHDB9981** + **Emerger** (x2)	2.0	2.3	1.0	***4.3**	1.7	0.0
Anthem, then **AHDB9981** + **Hurricane** (x2)	2.0	2.2	1.7	***2.7**	1.0	0.7
Anthem, then **AHDB9981** + **Huricane** + **Emerger** (x2)	***4.3**	***3.5**	1.3	***4.5**	***2.7**	0.0

p-value	<0.001	0.007	0.018	<0.001	<0.001	0.283
d.f.	14	13	14	14	13	14
L.S.D.	1.967	2.518	2.018	0.8301	1.294	0.6480

* significantly higher than untreated control AND >2.0.

Table 2. Mean percentage weed cover values (back-transformed) at Timing D, and two and eight weeks after Timing D treatment application.

Trt. No.	Mean weed cover (%)									
	Site 1						Site 2			
	(28/06/19) Timing D		+ 2 weeks		+ 8 weeks		(12/07/19) Timing D		+ 2 weeks†	
	Ang.	Back-trans	Ang.	Back-trans	Ang.	Back-trans	Ang.	Back-trans	Ang.	Back-trans
UTC	79.5	96.7	90.0	100.0	61.2	76.8	18.1	9.6	17.6	9.1
2	14.2	***6.1**	21.4	***13.3**	11.1	***3.7**	9.7	2.9	20.8	12.6
3	37.9	***37.7**	35.9	***34.5**	5.7	***1.0**	11.3	3.9	9.3	***2.6**
4	37.1	***36.4**	46.5	***52.5**	19.1	***10.7**	13.2	5.2	14.8	6.5
5	40.9	***42.8**	6.6	***52.9**	26.7	***8.3**	14.8	6.5	19.9	11.6
6	24.0	***16.5**	39.2	***40.0**	0.0	***0.0**	12.9	5.0	11.3	3.9
7	34.0	***31.2**	47.9	***55.1**	17.4	***9.0**	14.8	6.5	16.2	7.8
8	20.5	***12.3**	34.5	***32.1**	1.9	***0.1**	11.6	4.0	14.8	6.5
p-value	<0.001		0.006		<0.001		0.389		0.034	
d.f.	14		14		13		14		14	
L.S.D.	27.850		34.140		16.800		6.059		6.256	

UTC = untreated control.
* significantly different to untreated control.
† Weeds in trial area sprayed off to prevent their seeding into adjacent commercial crop, so no weed data available for later assessments.

Conclusion

- **AHDB9981** is a promising product for post-emergence weed control in parsnips, and was observed in these trials to be effective and crop safe at two rates when applied alone, and in tank mixes with **Emerger** and **Hurricane SC**. EAMU authorisation for post-emergence use of these three products in parsnips would be useful.

- Post-emergence application of **Defy + Goltix 70 SC** caused a significant reduction in crop population, with stunting a persistent foliar effect in the surviving crop.

- To achieve effective weed control, it is important to select the appropriate herbicide for the anticipated target weed spectrum and aim for an application timing when weeds are small.

Take home message

EAMU authorisations for post-emergence use of **Emerger**, **AHDB9981** or **Hurricane SC** should be applied for, to expand the range of actives available to parsnip growers. This would improve weed control and reduce the risk of resistance development.

Objective

To compare a number of herbicide tank-mixes with the current commercial standard (see "Application schedule") at one pre-emergence application timing and three post-emergence application timing for selectivity (crop safety) and efficacy in parsnips.

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

Deviations from EPPO guidance:

Test sites

Item	**Details**	
Location address	**Site 1** Field: 1031 – 914 Barn Field Tompsett Burgess Growers Sutton, Woodbridge IP12 3DT Suffolk Grid reference: TM 29705 46694	**Site 2** Field: 40 Acre (Green Mile Farm) Hammond Produce Babworth, Retford DN22 8JN Nottinghamshire Grid reference: SK 65913 81896
Crop	Parsnip	
Cultivar	Javelin	Javelin
Soil or substrate type	Freely draining slightly acid sandy soil	
Agronomic practice	See Appendix	
Prior history of site	See Appendix	

Trial design

Item	**Details**
Trial design:	Randomised block
Number of replicates:	3
Row spacing:	Site 1: 2m beds, 4 twin rows 90mm apart with 355mm row centres. Site 2: 72" beds, 4 double lines, 13" row spacing.
Plot size: (w x l)	2m x 6m
Plot size: (m^2)	$12m^2$
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

N/A†	Defy	prosulfocarb	BSN7H3020	800	Emulsifiable Concentrate
AHDB9997	Hurricane SC	diflufenican	500	17118244	Suspension Concentrate
AHDB9981	N/D	N/D	N/D	N/D	N/D
N/A†	Goltix 70 SC	metamitron	16028107	700	Suspension Concentrate
N/A†	Emerger	aclonifen	160	EV5600	Suspension concentrate

* label approval
† EAMU approval

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*	Anthem	A	1320	3.30
	Defy Goltix	B	1600 350	2.00 0.50
3	Anthem	A	1320	3.30
	Defy Emerger	B	1600 300	2.00 0.50
4	Anthem	A	1320	3.30
	AHDB9981	C, D	135	0.30
5	Anthem	A	1320	3.30
	AHDB9981	C, D	225	0.50
6	Anthem	A	1320	3.30
	AHDB9981 Emerger	C, D	135 300	0.30 0.50
7	Anthem	A	1320	3.30
	AHDB9981 Hurricane SC	C, D	135 25	0.30 0.05
8	Anthem	A	1320	3.30
	AHDB9981 Hurricane SC Emerger	C, D	135 25 300	0.30 0.05 0.50

* grower standard

Application details
Site 1

	Timing A	Timing B	Timing C	Timing D
Application date	30/04/2019	15/05/2019	31/05/2019	28/06/2019
Time of day	12:45 – 13:00	13:50 – 14:07	11:00 – 12:15	10:10 – 10:45
Crop growth stage (Max, min average BBCH)	BBCH00-03	N/K	BBCH11-12	BBCH14
Crop height (cm)	N/A	N/K	5.0	<30.0
Crop coverage (%)	N/A	N/K	N/K	30
Application Method	spray	spray	spray	spray
Application Placement	soil	soil	foliar	foliar
Application equipment	Oxford Precision	Oxford Precision	Oxford Precision	Oxford Precision

	Timing A	Timing B	Timing C	Timing D
Application date	30/04/2019	15/05/2019	31/05/2019	28/06/2019
	Sprayer (knapsack)	Sprayer (knapsack)	Sprayer (knapsack)	Sprayer (knapsack)
Nozzle pressure (bar)	2.0	2.0	2.0	2.0
Nozzle type	Flat fan	Flat fan	Flat fan	Flat fan
Nozzle size	02-F110	02-F110	02-F110	02-F110
Application water volume (L/ha)	200	200	200	200
Temperature of air – shade (°C)	16.8 – 17.0	18.1	20.9 – 21.0	18-19.1
Relative humidity (%)	58.7 – 60.0	40.7	46.0 – 47.9	70.4 – 70.1
Wind speed range (mph)	1.5 – 2.0	2.4	6.1 – 8.1	7.0 – 6.5
Dew presence (Y/N)	N	N	N	N
Temperature of soil - 10cm (°C)	N/K	N/K	18.9	N/K
Wetness of soil - 2-5 cm	N/K	N/K	dry	dry
Cloud cover (%)	80	15	80	95

Site 2

	Timing A	Timing B	Timing C	Timing D
Application date	12/05/2019	20/06/2019	02/07/2019	12/07/2019
Time of day	12:00 – 13:00	11:00 – 11:45	11:00 – 13:00	13:00 – 13:15
Crop growth stage (min., max. BBCH)	BBCH00-03	BBCH13	BBCH14	BBCH14
Crop height (cm)	N/A	3.0	15.0	N/K
Crop coverage (%)	N/A	10.0	35.0	N/K
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 (bar)	2.0	2.0	2.0	2.0
Nozzle type	Flat fan	Flat fan	Flat fan	Flat fan
Nozzle size	03F110	03F110	03F110	03F110
Application water (L/ha)	200	200	200	200
Temperature of air – shade (°C)	14.2 – 14.0	14.2 – 13.4	17.1 – 18.9	21.7
Relative humidity (%)	74.2 – 76.8	56.2 – 46.9	56.4 – 69.2	53.5
Wind speed range (mph)	2.4 – 1.0	7.6 – 5.9	2.3 – 3.5	5.7 – 6.1
Dew presence (Y/N)	N	N	N	N
Temperature of soil – 10cm (°C)	10.2	14.3	17.1	23.8
Wetness of soil (2-5 cm)	damp	damp	dry	dry

Cloud cover (%)	5	75	30	90

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

Common name	Scientific Name	EPPO Code		Infection level* at start of assessment period (Timing D + 2 weeks)	Infection level* mid-assessment period (Timing D + 4 weeks)	Infection level* at end of assessment period (Timing D + 8 weeks)
Broad leaved weeds and grasses	*N/A*	3WEEDT	SITE 1	96.7%	100.0%	76.8%
			SITE 2	9.6%	9.1%	-

* average weed cover (back-transformed).

Assessment details

Site 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)
15/05/2019	15	10	efficacy, phytotox	Phytotox (scale 0-10, 10 = Dead), weed species presence, plant population count.
28/06/2019	59	13-15	efficacy, phytotox	Phytotox (scale 0-10, 10 = Dead), percent weed cover (whole plot score, plus percent cover by species), plant population count.
11/07/2019	72	14-15	efficacy, phytotox	Phytotox (scale 0-10, 10 = Dead), percent weed cover (whole plot score, plus percent cover by species), plant population count.
25/07/2019	86	18-19	efficacy, phytotox	Phytotox (scale 0-10, 10 = Dead), percent weed cover (whole plot score, plus percent cover by species).
22/08/2019	114	N/K	efficacy, phytotox	Phytotox (scale 0-10, 10 = Dead), percent weed cover (whole plot score, plus percent cover by species).

* DA – days after Timing A application

Site 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)
20/06/2019	39	13	efficacy	Percentage of weed cover (whole plot score, plus scores per weed species).
02/07/2019	51	14	efficacy, phytotox	Phytotoxicity (scale 0-10; 10 = dead), percentage of weed cover (whole plot score, plus scores per weed species), plant population count.
15/07/2019	64	14	efficacy, phytotox	Phytotoxicity (scale 0-10; 10 = dead), percentage of weed cover (whole plot score, plus scores per weed species), plant population count.

29/07/2019	78	N/K	efficacy, phytotox	Phytotoxicity (scale 0-10; 10 = dead), percentage of weed cover (whole plot score, plus scores per weed species).
17/09/2019	128	N/K	phytotox	Phytotoxicity (scale 0-10; 10 = dead).

* DA – days after Timing A application

Statistical analysis

The trials had randomised block designs, each comprising seven treatments, including an untreated control and grower standard treatment. Treatments were replicated three times.

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 and the back transformed means presented, from which the % reduction in weeds was calculated using Abbott's formula.

All data were analysed by ANOVA using Genstat (18th edition) by Emily Lawrence (ADAS).

Results

Phytotoxicity

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

Phytotoxicity was recorded using the following scale:

Crop tolerance score	(% phytotoxicity) **Equivalent to crop damage**
0	*(no damage)* 0%
1	10%
***2**	20%
3	30%
4	40%
5	50%
6	60%
7	70%
8	80%
9	90%
10	*(complete crop kill)* 100%

* ≤2 = acceptable damage, i.e. damage unlikely to reduce yield, and acceptable to the farmer.

There were relatively few phytotoxic effects observed from the treatments assessed in this trial.

At Site 1, three treatments did not show any significant damage to the crop at any point during the assessment period—**Anthem, then AHDB9981 (low rate)**; **Anthem, then AHDB9981 (high rate)**; and **Anthem, then AHDB9981 + Emerger**.

There was some damage observed at the two-week assessment for **Anthem, then AHDB9981 + Hurricane SC**—which was slight stunting and some foliar discolouration—and at both the Timing D and two-week assessments for **Anthem, then AHDB9981 + Hurricane SC + Emerger**—foliar yellowing at the earliest assessment, followed by stunted growth. By the final assessment, the crop had grown through the effects of these treatments are was of commercially acceptable quality.

While the five aforementioned treatments showed no significant damage at the final assessment, the two remaining treatments did show persistent phytotoxic effects at Site 1.

Most notable were the phytotoxic effects observed following treatment with **Anthem, then Defy + Goltix 70 SC**. This treatment had a significant impact on crop quality at Site 1, killing most of the parsnips and leaving the remaining crop stunted. Also, crop treated with **Anthem, then Defy + Emerger** was noted to be slightly stunted at the final assessment.

Similar treatment effects were observed at Site 2, though no phytotoxic treatment effects persisted until the final assessment. **Anthem, then Defy + Goltix** appeared to have quite a harsh effect on the crop in the earlier assessments—stunting the crop—but the crop grew through these by the end of the trial. The early assessments of the effects of **Anthem, then AHDB9981 + Hurricane SC** and **Anthem, then AHDB9981 + Hurricane SC + Emerger** on crop phytotoxicity showed some crop damage, as at Site 1. Some foliar discolouration was also noted at the Timing D assessment for **Anthem, then AHDB9981 + Emerger**, but for this and the other tank-mix treatments, no notable crop phytotoxicity was apparent at the final assessment.

Table 1. Mean phytotoxicity scores at Timing D, and two and eight weeks (nine weeks for Site 2) after Timing D treatment application.

Treatment	Mean crop damage scores (0-10)					
	Site 1			Site 2		
	(28/06/19) **Timing D**	**+ 2 weeks**	**+ 8 weeks**	(12/07/19) **Timing D**	**+ 2 weeks**	**+ 9 weeks**
Untreated	0.0	0.0	0.0	0.0	0.0	0.0
Anthem, then **Defy** + **Goltix**	***5.0**	***5.0**	***4.0**	***8.0**	***5.7**	0.3
Anthem, then **Defy** + **Emerger**	0.3	0.0	***3.0**	0.7	0.0	0.3
Anthem, then **AHDB9981** (x2) (low rate)	1.0	0.3	1.0	1.7	0.0	0.0
Anthem, then **AHDB9981** (x2) (high rate)	1.7	1.7	1.0	2.0	0.0	0.0
Anthem, then **AHDB9981** + **Emerger** (x2)	2.0	2.3	1.0	***4.3**	1.7	0.0
Anthem, then **AHDB9981** + **Hurricane**(x2)	2.0	2.2	1.7	***2.7**	1.0	0.7
Anthem, then **AHDB9981** + **Hurricane** + **Emerger** (x2)	***4.3**	***3.5**	1.3	***4.5**	***2.7**	0.0
p-value	<0.001	0.007	0.018	<0.001	<0.001	0.283
d.f.	14	13	14	14	13	14
L.S.D.	1.967	2.518	2.018	0.8301	1.294	0.6480

* significantly higher than untreated control AND >2.0.

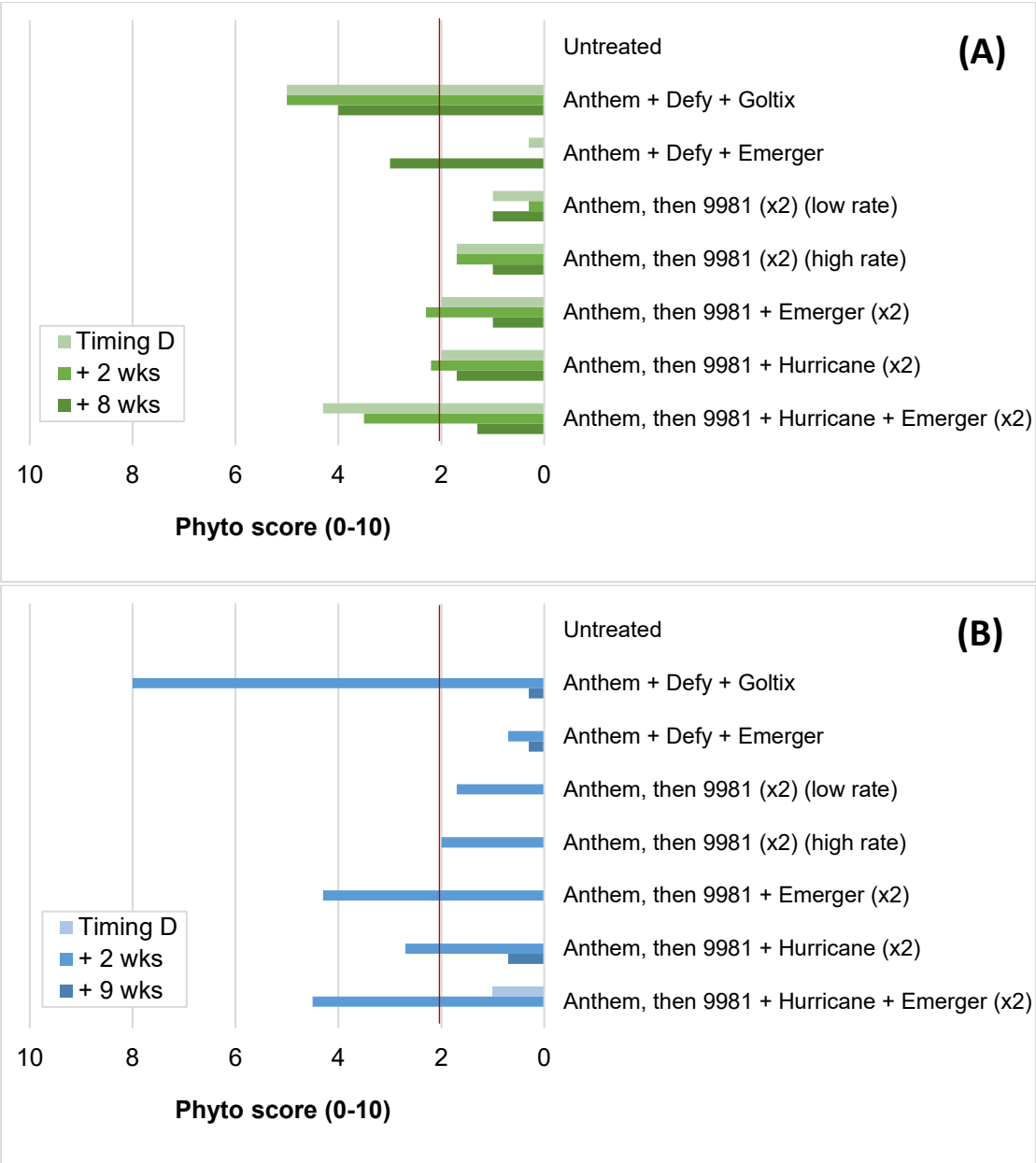


Figure 1. Mean phytotoxicity scores at Timing D, and two and eight weeks (nine weeks for Site 2) after Timing D treatment application (Site 1 **(A)** and Site 2 **(B)**). Scores ≤2 deemed commercially acceptable damage (as indicated by red line).

Weed control – mean percentage weed cover

The results for the mean percentage weed cover per treatment are presented in **Table 2** and **Figure 2**. The percent reduction in weed cover compared to the untreated control was calculated from these figures (using Abbott's formula), and results for each treatment are listed in **Table 3**.

At Site 1, fat hen was the main weed species, with groundsel, blackgrass and black bindweed also present. Groundsel, and volunteer wheat and potatoes were most common at Site 2.

At Site 1, all treatments showed significantly lower weed cover than the untreated control plots across all assessments. Treatment 2 (**Anthem,** then **Defy** + **Goltix 70 SC**) showed consistently effective control of weeds, though was one of the treatments which was also harsh on the parsnip crop.

All of the crop safe treatments offered effective weed control. Most promising were **Anthem, then AHDB9881 + Emerger** and **Anthem, then AHDB9881** + **Hurricane SC** + **Emerger**,

showing an average of 0.1% and 0.0% weed cover respectively at eight weeks after the final treatment application.

There were notably fewer weeds at Site 2 than Site 1, with the average weed cover in the Site 1 untreated control 100% compared to 9.1% at Site 2 at the same assessment timing (two weeks after the final treatment application). Due to this low weed level at Site 2, there were no significant differences in weed cover between the treatments.

Table 2. Mean percentage weed cover values (back-transformed) at Timing D, and two and eight weeks after Timing D treatment application.

Trt. No.	Mean weed cover (%)									
	Site 1						Site 2			
	(28/06/19) Timing D		+ 2 weeks		+ 8 weeks		(12/07/19) Timing D		+ 2 weeks†	
	Ang.	Back-trans	Ang.	Back-trans	Ang.	Back-trans	Ang.	Back-trans	Ang.	Back-trans
UTC	79.5	96.7	90.0	100.0	61.2	76.8	18.1	9.6	17.6	9.1
2	14.2	***6.1**	21.4	***13.3**	11.1	***3.7**	9.7	2.9	20.8	12.6
3	37.9	***37.7**	35.9	***34.5**	5.7	***1.0**	11.3	3.9	9.3	***2.6**
4	37.1	***36.4**	46.5	***52.5**	19.1	***10.7**	13.2	5.2	14.8	6.5
5	40.9	***42.8**	6.6	***52.9**	26.7	***8.3**	14.8	6.5	19.9	11.6
6	24.0	***16.5**	39.2	***40.0**	0.0	***0.0**	12.9	5.0	11.3	3.9
7	34.0	***31.2**	47.9	***55.1**	17.4	***9.0**	14.8	6.5	16.2	7.8
8	20.5	***12.3**	34.5	***32.1**	1.9	***0.1**	11.6	4.0	14.8	6.5
p-value		<0.001		0.006		<0.001		0.389		0.034
d.f.		14		14		13		14		14
L.S.D.		27.850		34.140		16.800		6.059		6.256

UTC = untreated control.
* significantly different to untreated control.
† Weeds in trial area sprayed off to prevent their seeding into adjacent commercial crop, so no weed data available for later assessments.

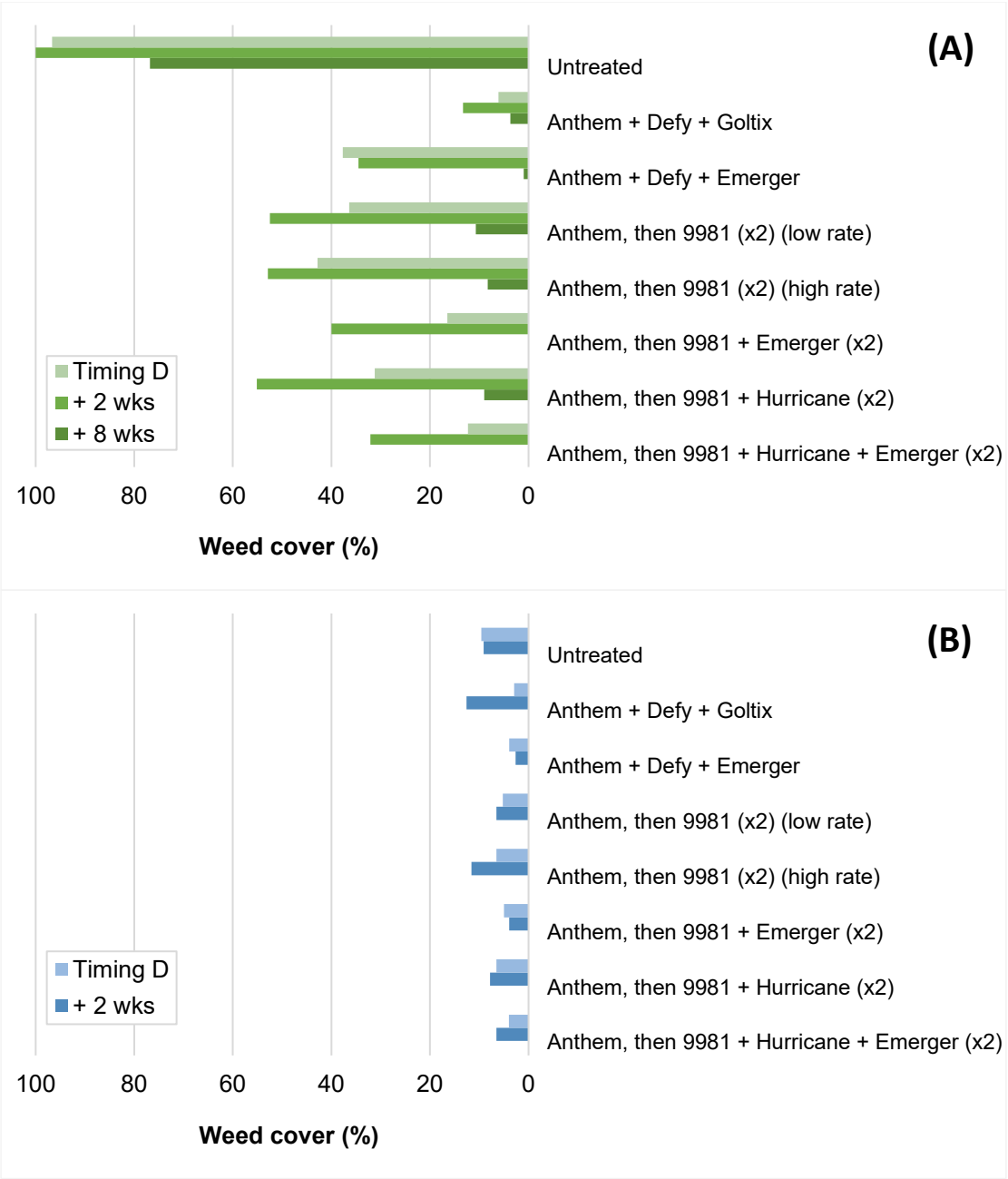


Figure 2. Mean weed cover (%; back-transformed values) at Timing D, and two and eight weeks (for Site 1) after Timing D treatment application (Site 1 **(A)** and Site 2 **(B)**).

Table 3. Percentage reduction in weed cover at Timing D, and two and eight weeks (for Site 1) after Timing D treatment application (calculated using Abbott's formula). Negative values (in blue) indicated an increase in weed cover compared to the untreated control.

Treatment	Weed cover reduction (%)				
	Site 1			Site 2	
	(28/06/19) **Timing D**	**+ 2 weeks**	**+ 8 weeks**	(12/07/19) **Timing D**	**+ 2 weeks**
Anthem, then **Defy** + **Goltix**	93.7	86.7	95.2	70.3	-37.6

Anthem, then **Defy** + **Emerger**	61.0	65.5	98.7	59.8	71.6
Anthem, then **AHDB9981** (x2) (low rate)	62.3	47.5	86.0	46.0	28.9
Anthem, then **AHDB9981** (x2) (high rate)	55.7	47.1	89.2	32.4	-26.7
Anthem, then **AHDB9981** + **Emerger** (x2)	82.9	60.0	-	47.9	57.8
Anthem, then **AHDB9981** + **Hurricane** (x2)	67.7	44.9	88.3	32.4	14.7
Anthem, then **AHDB9981** + **Hurricane** + **Emerger** (x2)	87.3	67.9	99.9	58.1	28.9

Plant population

There were no significant reductions in plant population at Site 1 for most of the treatments—presented in **Table 4**—with the exception of **Anthem, then Defy + Goltix 70 SC**. At the Timing D assessment, the average plant population in plots that received this treatment was significantly lower than the untreated control, with a 46% reduction in numbers. Most of the crop had four true leaves at the timing of this assessment. This difference was not significant at the Timing B assessment, with plots only having been treated with Anthem at this point. There were no significant reductions or differences in plant population from any of the treatments applied at Site 2.

Table 4. Plant population counts from two timings at each trial site; values are treatment averages of the number of parsnip plants present in a 0.5 m length of a single central row.

Trt. No.	Mean plant population (№ plants in 0.5 m of single row)			
	Site 1		Site 2	
	(15/05/19) **Timing B**	(28/06/19) **Timing D**	(02/07/19) **Timing C**	(12/07/19) **Timing D**
Untreated	11.0	9.8	15.3	16.7
Anthem, then **Defy** + **Goltix**	9.7	***5.3**	15.0	15.0
Anthem, then **Defy** + **Emerger**	9.5	9.8	15.0	15.3
Anthem, then **AHDB9981** (x2) (low rate)	8.0	10.8	16.3	20.0
Anthem, then **AHDB9981** (x2) (high rate)	10.0	9.5	15.0	15.0
Anthem, then **AHDB9981** + **Emerger** (x2)	8.5	10.8	18.7	16.3

Anthem, then **AHDB9981** + **Hurricane** (x2)	7.5	9.0	12.7	13.7
Anthem, then **AHDB9981** + **Hurricane** + **Emerger** (x2)	9.2	10.2	16.7	17.7
p-value	0.630	0.002	0.184	0.081
d.f.	14	14	14	14
L.S.D.	3.949	2.156	4.000	3.900

Discussion

Of the treatments assessed in these trials, five appeared crop safe and gave statistically significant weed control—**Anthem, then AHDB9981 (low rate)**; **Anthem, then AHDB9981 (high rate)**; **Anthem, then AHDB9981 + Emerger**; **Anthem, then AHDB9981 + Hurricane**; and **Anthem, then AHDB9981 + Hurricane + Emerger**. By the conclusion of the trial, eight weeks after the final treatment application, all these treatments offered a significant reduction in weed cover compared to the untreated control, with none exhibiting any notable phytotoxic symptoms.

Regarding the treatments' effects on plant population, there were no significant differences between the treatments and the untreated crop at the first assessment at Site 1. However, at this site's second assessment, the application of **Defy + Goltix** did show a significant population reduction (no differences observed for other treatments). There were no significant reductions in plant population at Site 2 at either assessment. This can be attributed to the treatment application delay leading to the crop's larger size—and consequent increased resilience—at Site 2.

These trials also highlighted the significance of application timing in treatment efficacy. At Site 1, there was a heavy weed burden, with a mean weed cover of 100% two weeks after the final treatment application. However, all treatments appeared to offer significant and persistent control. While Site 2 had fewer weeds—with a mean weed cover of 9.1% two weeks after the final treatment application—but there were (almost) no significant treatment effects. With weather causing a delay in the Site 2 treatment applications, the Timing B application was made 39 days after the previous treatment application, whereas the spray interval was only 15 days at Site 1. This could explain the apparent differences in treatment efficacy between the two sites. Due to the delay in application timing, the Site 2 weeds and crop were larger when they were treated, thus treatments were less effective at this site (relative to the potential weed cover, as seen in the untreated plots).

The differences in each site's weed spectrum is also significant. At Site 1, there was considerably more fat hen than any other weed species. Mayweed, annual meadow grass and groundsel were also common, though the latter had naturally senesced before the final assessment. At Site 2, volunteer wheat was the most common weed, followed by groundsel and volunteer potatoes. This is noteworthy as **Defy**, **Hurricane SC** and **Emerger** are currently authorised for use in wheat and/or potato crops, hence their inherent inefficacy at Site 2 given the weed spectrum.

Emerger is authorised under EAMU 1601/19 for pre-emergence use on parsnip. A post-emergence EAMU authorisation for this product would also be very useful as its performance was promising in this trial.

The use of **AHDB9981** and **Hurricane SC** on parsnips is not currently approved, though these products also showed promise in this trial. **AHDB9981** was both screened at different application rates and tested in various tank-mix combinations, and by the conclusion of the trials showed lasting efficacy without any persistent phytotoxic effects. Similarly, **Hurricane SC**—which was trialed as a tank-mix partner—contributed to treatments which appeared

effective and crop safe by the final assessment. These products would be valuable additions to parsnip growers' weed control options, and pursual of EAMUs would be useful.

Conclusions

- **AHDB9981** is a promising product for post-emergence weed control in parsnips, and was observed in these trials to be effective and crop safe at two rates when applied alone, and in tank mixes with Emerger and Hurricane SC. EAMU authorisation for post-emergence use of these three products in parsnips would be useful.

- Post-emergence application of **Defy + Goltix 70 SC** caused a significant reduction in crop population, with stunting a persistent foliar effect in the surviving crop.

- To achieve effective weed control, it is important to select the appropriate herbicide for the anticipated target weed spectrum and aim for an application timing when weeds are small.

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 Jason Ambrose of Tompsett Burgess Growers, and Philip Lilley of Hammond Produce.

Appendix

a. Crop differences between sites.

Figure 3. Untreated plots at the Timing C treatment application at Site 1 (31/05/19) and Site 2 (02/07/19).

b. Crop diary – events related to growing crop

Site 1

Crop	Cultivar	Drilling date	Bed width
Parsnips	Javelin	15/04/2019	2m beds, 4 twin rows 90mm apart with 355mm row centres.

Previous cropping

Year	Crop
2018	Sugar beet
2017	Spring Barley

Cultivations

Date	Description
23/03/2019	Sub-soiling
	Destoning
	Ridge forming
15/04/2019	Bed forming
	Headland cultivation

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

Date	Product	Rate	Unit
21/02/19	Vegetable fertiliser	1269.484	kg/ha
	Potash	250.000	kg/ha
	Magnesium	95.000	kg/ha
16/05/19	Emupol	150.000	L/ha
23/05/19	Nitrogen (34%)	120.000	kg/ha
14/06/19	Nitrogen (34%)	118.513	kg/ha
17/06/19	Opte-Manganese	3.000	L/ha
29/06/19	Boron	2.000	L/ha
11/07/19	Decis Protech	0.500	L/ha
	Thio-s	5.000	L/ha
15/07/19	Nitrogen (34%)	114.025	kg/ha
26/07/19	Omex 3x	3.000	L/ha
08/08/19	Thio-s	5.000	L/ha
21/08/19	Opte-Manganese	5.000	L/ha

Pesticides applied to trial area

Date	Product	Rate	Unit
15/04/19	Vydate 10G	12.000	kg/ha
03/06/19	Biscaya	0.400	L/ha
	Decis Protech	0.500	L/ha
17/06/19	Decis Protech	0.500	L/ha
29/06/19	Hallmark with Zeon Technology	0.100	L/ha
11/07/19	Amistar	0.700	L/ha
26/07/19	Minecto One	0.185	kg/ha
	Rudis	0.400	L/ha
08/08/19	Hallmark with Zeon Technology	0.100	L/ha
21/08/19	Hallmark with Zeon Technology	0.100	L/ha
	Nativo 75 WG	0.300	L/ha

Details of irrigation regime

Date	Rate
29/04/2019	Irrigation, 20 mm

Site 2

Crop	Cultivar	Drilling date	Bed width
Parsnips	Javelin	30/04/2019	72” bed, 4 double lines, 13” row spacing

Previous cropping

Year	Crop
2018	Winter wheat
2017	Maize
2016	Savoy cabbage

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

Date	Product	Rate	Unit
30/02/2019	Gypsum	2500.000	kg/ha
20/04/2019	15:0:25	344.403	kg/ha
19/06/2019	Ammonium nitrate	96.449	kg/ha
01/07/2019	Tecal	1.000	L/ha
	EPSO Top (bittersalz)	2.430	kg/ha
04/07/2019	Maxicrop Triple	1.000	L/ha
	TTL Plus	0.300	L/ha
	Maxicrop Triple	0.975	L/ha
	TTL Plus	0.424	L/ha
	Tecal	0.975	L/ha
	EPSO Top (bittersalz)	2.360	kg/ha
	Manganese liquid 15%	2.919	L/ha
11/07/2019	Ammonium nitrate	149.673	kg/ha
12/07/2019	EPSO Top (bittersalz)	24.910	kg/ha
25/07/2019	Boron liquid 15%	1.000	L/ha
	EPSO Top (bittersalz)	2.523	kg/ha
07/08/2019	Ammonium nitrate	95.421	kg/ha
08/08/2019	Muriate of potash	9.893	kg/ha
	Manganese liquid 15%	2.009	L/ha
	EPSO Top (bittersalz)	2.430	kg/ha
12/08/2019	TTL Plus	4.000	L/ha
23/08/2019	Omex – Bio 15	3.000	L/ha

	TTL Plus	0.500	L/ha
05/09/2019	Omex – Calmax	0.748	L/ha

Pesticides applied to trial area

Date	Product	Rate	Unit
30/04/2019	Vydate 10G	15.000	kg/ha
09/06/2019	Biscaya	0.400	L/ha
10/06/2019	SL 567A	0.940	L/ha
01/07/2019	Toledo	0.600	L/ha
	Colt 10 CS	0.150	L/ha
12/07/2019	Minecto One	0.181	kg/ha
	Reflect	0.598	L/ha
25/07/2019	Colt 10 CS	0.150	L/ha
	Amistar Top	0.692	L/ha
08/08/2019	Nativo 75 WG	0.299	kg/ha
	Hallmark with Zeon Technology	0.150	L/ha
23/08/2019	Amistar Top	1.000	L/ha
	Lambdastar	0.075	L/ha
05/09/2019	Reflect	0.393	L/ha
	Signum	0.495	kg/ha
	Hallmark with Zeon Technology	0.150	L/ha

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

Site 1:

Date	Event
30/04/2019	Timing A treatment application.
15/05/2019	Timing B treatment application. Trial assessment; crop phyto, weed cover population counts.
31/05/2019	Timing C treatment application.
28/06/2019	Timing D treatment application. Trial assessment; crop phyto, weed cover population counts.
11/07/2019	Trial assessment; crop phyto, weed cover.
25/07/2019	Trial assessment; crop phyto, weed cover.
22/08/2019	Trial assessment; crop phyto, weed cover.

Site 2:

Date	Event
12/05/2019	Timing A treatment application.
20/06/2019	Timing B treatment application.

	Trial assessment; weed cover.
02/07/2019	Timing C treatment application. Trial assessment; crop phyto, weed cover, population counts.
12/07/2019	Timing D treatment application.
15/07/2019	Trial assessment; crop phyto, weed cover, population counts.
29/07/2019	Trial assessment; crop phyto, weed cover.
17/09/2019	Trial assessment; crop phyto.

d. Climatological data during study period.

Site 1

Date	**Min. temp.** (°C)	**Max. temp.** (°C)	**Precip.** (mm)
23/04/2019	9.0	18.0	0
24/04/2019	23.0	25.0	0
25/04/2019	19.5	26.0	4
26/04/2019	19.5	24.5	0
27/04/2019	13.5	20.0	2
28/04/2019	13.5	16.5	2
29/04/2019	13.5	22.0	0
30/04/2019	5.0	19.5	0
01/05/2019	4.0	13.5	0
02/05/2019	9.0	16.5	4
03/05/2019	5.5	10.5	2
04/05/2019	3.0	9.5	2
05/05/2019	4.0	11.5	1
06/05/2019	4.5	12.5	0
07/05/2019	2.5	14.5	0
08/05/2019	8.5	13.5	31
09/05/2019	7.5	14.5	2
10/05/2019	7.0	13.0	1
11/05/2019	6.5	13.5	0
12/05/2019	2.5	15.0	0
13/05/2019	2.5	16.0	0
14/05/2019	4.0	17.0	0
15/05/2019	4.5	18.5	0
16/05/2019	6.0	17.5	0
17/05/2019	10.5	15.5	0
18/05/2019	9.5	19.5	0
19/05/2019	9.0	17.5	1
20/05/2019	10.0	19.5	2
21/05/2019	8.0	23.0	0
22/05/2019	7.5	22.5	0
23/05/2019	10.0	25.5	0
24/05/2019	10.5	24.5	0
25/05/2019	10.0	21.5	0

26/05/2019	14.5	24.0	0
27/05/2019	9.0	20.0	8
28/05/2019	8.0	15.0	10
29/05/2019	6.0	18.5	2
30/05/2019	13.5	26.0	2
31/05/2019	12.5	22.5	0
01/06/2019	12.0	24.0	0
02/06/2019	15.0	27.5	0
03/06/2019	13.0	23.5	0
04/06/2019	10.0	20.0	9
05/06/2019	12.0	19.0	5
06/06/2019	11.0	19.5	6
07/06/2019	10.5	17.0	3
08/06/2019	11.5	18.0	6
09/06/2019	9.0	20.5	0
10/06/2019	11.5	14.5	32
11/06/2019	10.0	20.5	15
12/06/2019	11.5	15.5	8
13/06/2019	11.0	17.5	9
14/06/2019	12.0	21.0	0
15/06/2019	12.0	22.0	0
16/06/2019	10.5	21.0	1
17/06/2019	13.5	23.5	0
18/06/2019	11.5	24.0	8
19/06/2019	13.0	18.5	8
20/06/2019	14.5	22.5	1
21/06/2019	10.5	23.5	0
22/06/2019	13.0	22.5	0
23/06/2019	11.5	25.0	0
24/06/2019	17.0	27.5	0
25/06/2019	17.5	24.0	17
26/06/2019	14.5	18.5	0
27/06/2019	13.0	20.0	0
28/06/2019	13.5	22.0	0
29/06/2019	13.5	28.5	0
30/06/2019	16.5	29.0	0
01/07/2019	13.0	24.5	0
02/07/2019	11.0	23.0	0
03/07/2019	8.0	25.0	0
04/07/2019	7.5	27.0	0
05/07/2019	14.0	29.0	0
06/07/2019	14.5	23.5	3
07/07/2019	12.0	20.5	1
08/07/2019	9.0	21.0	0
09/07/2019	12.5	19.0	0
10/07/2019	15.5	23.5	0
11/07/2019	16.0	25.5	0

12/07/2019	16.0	23.0	0
13/07/2019	14.5	21.0	0
14/07/2019	13.5	19.5	0
15/07/2019	12.5	18.0	0
16/07/2019	8.5	26.5	0
17/07/2019	14.5	22.5	0
18/07/2019	16.0	20.0	2
19/07/2019	12.0	20.0	4
20/07/2019	16.5	22.0	16
21/07/2019	13.5	21.5	0
22/07/2019	15.5	26.0	0
23/07/2019	16.0	26.5	0
24/07/2019	19.0	28.5	5
25/07/2019	18.0	28.5	3
26/07/2019	19.5	25.5	4
27/07/2019	16.0	20.0	13
28/07/2019	15.5	18.0	22
29/07/2019	13.5	22.5	0

Site 2

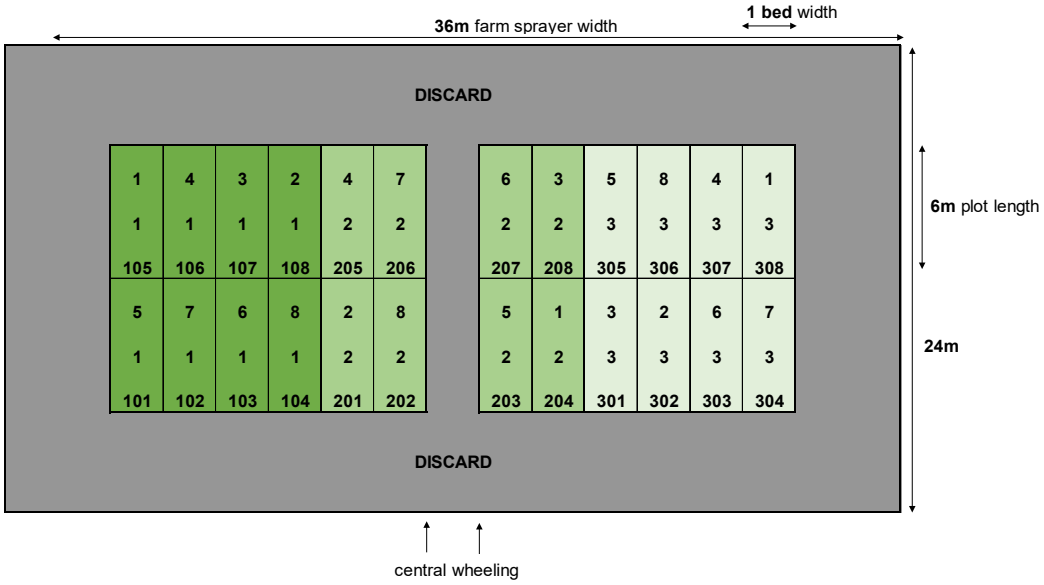
Date	Min. temp. (°C)	Max. temp. (°C)	Rainfall (mm)
12/05/2019	2	17	0
13/05/2019	5	20	0
14/05/2019	7	20	0
15/05/2019	6	20	0
16/05/2019	4	17	0
17/05/2019	9	19	0
18/05/2019	10	16	0
19/05/2019	10	19	0
20/05/2019	8	20	0
21/05/2019	9	20	0
22/05/2019	9	20	0
23/05/2019	8	21	0
24/05/2019	10	21	0
25/05/2019	11	21	0
26/05/2019	12	20	2
27/05/2019	10	18	7
28/05/2019	8	16	6
29/05/2019	5	17	2
30/05/2019	15	23	0
31/05/2019	14	22	0
01/06/2019	14	24	0
02/06/2019	12	23	2
03/06/2019	11	21	0
04/06/2019	9	18	2
05/06/2019	9	17	0
06/06/2019	8	20	0
07/06/2019	6	18	4
08/06/2019	10	14	7
09/06/2019	8	19	0

Date	Min. temp. (°C)	Max. temp. (°C)	Rainfall (mm)
10/06/2019	9	15	12
11/06/2019	10	13	30
12/06/2019	10	16	22
13/06/2019	8	14	8
14/06/2019	8	17	6
15/06/2019	9	18	1
16/06/2019	7	19	0
17/06/2019	13	21	0
18/06/2019	12	19	2
19/06/2019	12	19	2
20/06/2019	8	21	1
21/06/2019	7	19	0
22/06/2019	8	22	0
23/06/2019	11	20	3
24/06/2019	14	21	0
25/06/2019	13	17	6
26/06/2019	9	15	0
27/06/2019	8	21	0
28/06/2019	12	20	0
29/06/2019	10	29	0
30/06/2019	15	23	0
01/07/2019	11	19	0
02/07/2019	9	19	0
03/07/2019	9	21	0
04/07/2019	11	23	0
05/07/2019	15	23	0
06/07/2019	12	21	1
07/07/2019	10	20	0
08/07/2019	11	19	0
09/07/2019	12	19	0
10/07/2019	15	23	0
11/07/2019	15	24	1
12/07/2019	13	24	2
13/07/2019	13	22	3
14/07/2019	10	19	2
15/07/2019	10	23	0
16/07/2019	11	24	0
17/07/2019	15	25	1
18/07/2019	14	20	0
19/07/2019	10	19	4
20/07/2019	12	21	2
21/07/2019	12	22	0
22/07/2019	17	27	0
23/07/2019	14	30	0
24/07/2019	18	28	3
25/07/2019	16	35	0
26/07/2019	19	23	0
27/07/2019	15	19	19
28/07/2019	15	19	2
29/07/2019	14	23	1
30/07/2019	15	24	3

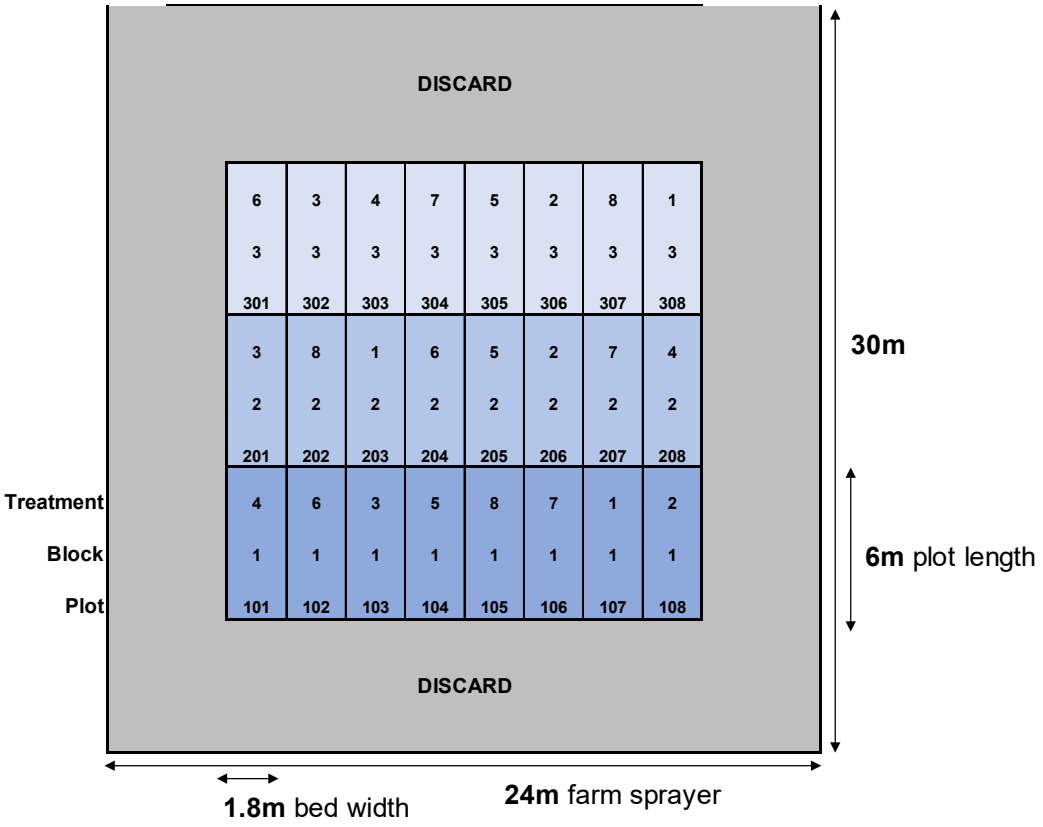
Date	Min. temp. (°C)	Max. temp. (°C)	Rainfall (mm)
31/07/2019	16	20	12
01/08/2019	14	23	0
02/08/2019	14	21	0
03/08/2019	10	24	0
04/08/2019	16	25	0
05/08/2019	14	22	3
06/08/2019	13	22	3
07/08/2019	13	21	0
08/08/2019	12	23	0
09/08/2019	16	24	16
10/08/2019	15	21	2
11/08/2019	11	20	0
12/08/2019	9	17	0
13/08/2019	10	18	1
14/08/2019	10	16	7
15/08/2019	11	19	0
16/08/2019	11	17	16
17/08/2019	13	21	0
18/08/2019	12	21	1
19/08/2019	11	20	0
20/08/2019	10	18	1
21/08/2019	12	21	0
22/08/2019	15	22	0
23/08/2019	15	25	0
24/08/2019	13	27	0
25/08/2019	12	30	0
26/08/2019	14	29	0
27/08/2019	15	29	0
28/08/2019	11	20	5
29/08/2019	9	21	0
30/08/2019	15	22	0
31/08/2019	9	19	1
01/09/2019	9	17	2
02/09/2019	10	19	1
03/09/2019	15	22	0
04/09/2019	12	17	2
05/09/2019	9	17	0
06/09/2019	12	18	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 *Authorised signatory*

Certification Number
ORETO 409

HSE
Chemicals Regulation Division

Department of Agriculture and Rural Development