

SCEPTREPLUS

Final Trial Report

Trial code:	SP35. 2018
Title:	AHDB SceptrePlus parsnip volunteer potato control screen
Crop	Group: Field vegetables – Parsnip (apiaceae), other umbelliferous root vegetables
Target	Volunteer potatoes, SOLTU (<i>Solanum tuberosum</i>) EPPO1/99(3) Weeds in root vegetables
Lead researcher:	Angela Huckle
Organisation:	RSK ADAS
Period:	May 2018 – March 2019
Report date:	20 th December 2019
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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

20/12/2019.....
Date


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Authors signature

Trial Summary

Introduction

Volunteer potato control has become difficult since the loss of linuron in June 2018. In addition, changes to the approval for Defy (prosulfocarb) have also made control more difficult with the useful later post-emergence applications (up to 3TL) no longer being permitted. This is because the standard approach was to apply a combination of linuron plus prosulfocarb at an appropriate timing to suppress or control the potatoes. With this tank mix no longer available, alternative options for control are urgently required.

The aim of this trial is to screen herbicides that show potential for volunteer potato control when used in tank mixes with Defy and adjuvants, looking to identify any that can replicate the effects of the linuron + prosulfocarb standard.

Method

The trial was sited at a commercial parsnip grower on freely draining lime-rich loamy soil in Suffolk. A randomised block design was used, with three replicates of twenty treatments, including two untreated controls and a grower standard for comparison. There were sixty plots in total, each 2m wide by 8m long (*see appendix for trial plan*). The volunteer potatoes were naturally occurring and therefore growth stages were variable.

Treatment application was with a 2m boom and Oxford Precision Sprayer backpack, at 200 L/ha water volume. Treatments were applied at three timings. The first was applied when the volunteer potatoes were just emerged or at small rosette, the second when potato foliage reached a small rosette to stem extension, and the third treatment applied at stem extension and flowering. The parsnips were at two to three true leaves at the first application timing.

The plots were assessed on six occasions, focusing on crop and potato phytotoxicity. Assessments were carried out at each of the three spray timings, and at approximately two, four and eight weeks after the final treatment application. In addition, two counts of both crop and potato populations were made.

Results and discussion

Identifying treatments with a possibility to control volunteer potatoes is a challenge as those products and treatment combinations with the potential of severely reducing growth or killing the potatoes, tend to also be on the borderline of crop safety for parsnips or carrots. Afalon + Defy was the safe commercial standard before linuron's revocation in June 2018, but this mix could also be unpredictable in its efficacy, and in this trial did not have a great effect on the volunteer potatoes despite controlling most of the weeds.

The volunteer potatoes occurred naturally and were at varying growth stages when the treatments were applied. There were no significant differences between numbers of potatoes per plot at the start of the trial, and therefore there was an even distribution of potatoes across the trial area. At the 2nd application, there were only three treatments where a very slight—but not significant—reduction in the number of potatoes was observed; these were Chlorpropham + Phase II (esterified rape seed oil) + Lepton ZC, Hurricane SC + Phase II, and Hurricane + Phase II + Lepton ZC, with 0.3 to 2.0 fewer potatoes counted in the final population assessment. No further potato plant deaths were seen at subsequent efficacy assessments, and despite these reductions, there were no significant differences between the potato numbers in the second and final potato population count.

By the third and final treatment application, seven treatments were seen to have a significant effect on potatoes—these were; all treatment combinations where Hurricane SC was included, chlorpropham + Phase II + Lepton ZC, AHDB 9993 + Defy, and AHDB 9981 + Phase II. However, the observed effects only persisted to the end of the assessment period (at four weeks after the final application) in one treatment—Hurricane SC + Phase II. The moderate effects seen following treatment with chlorpropham + Phase II were first noted four weeks after application, but were not seen in earlier assessments; this was likely due to senescence—an early symptom of blight—rather than a treatment effect.

There was significant crop damage in the plots where Hurricane SC, AHDB 9993 or AHDB 9981 were applied, with effects persisting until two weeks after application (See *appendix for photos*). Hurricane SC caused bleaching and whitening in spots and blotches to the parsnip leaves, AHDB 9993 caused a diffuse yellowing on the leaves that were present at application, and AHDB 9981 caused yellow patches, and scorch to leaf edges when mixed with Defy or any of the adjuvants. However, there was no crop death. Chlorpropham was the safest treatment, causing very little effect.

The yellowing on the parsnip leaves from AHDB 9981 persisted the longest, and still gave significantly lower phytotoxicity scores (i.e. more damage) than the untreated, where it was mixed with Defy and Phase II at four weeks after application. The other treatment which also had significantly persistent phytotoxicity scores at four weeks after application was AHDB 9993 + Phase II + Lepton ZC.

The previously used standard, Afalon + Defy caused yellow edges and a little stunting during the period of application, but the crop recovered quickly and showed no symptoms at four weeks after application.

Hurricane SC + Phase II shows the greatest potential for volunteer potato control, but it has a very striking effect on the parsnips. However, no crop loss from this treatment was observed in this trial. Some of the potatoes were fairly large when the herbicide mixes were first applied and in photos, the new growth can be seen to be unaffected in the large plants. Smaller plants sustained more damage, and therefore timing may be important. The tricky balance is timing the application to be damaging to the potato and not the parsnip, and further work is required with the most promising treatment combinations.

Table 1. Summary of crop damage and effects on potatoes. Mean phytotoxicity scores at the final application date, and four weeks later. Values which are significantly different to untreated are starred. For the crop scores, values <8 are deemed commercially unacceptable, and are marked in **bold**. For potatoes, values ≤6 were deemed a moderate effect and are marked in **bold**.

Treatment	Mean crop damage (0-10)		Mean potato damage (0-10)	
	19 th Jul (Timing C)	15 th Aug (Timing C + 4 weeks)	19 th Jul (Timing C)	15 th Aug (Timing C + 4 weeks)
Untreated*	8.17	8.33	9.78	8.45
Afalon + Defy	8.33	10.00	8.33*	8.00
Chlorpropham + Defy	8.67	9.00	9.33	6.33
Chlorpropham + Phase II	8.33	6.67	9.33	6.00*
Chlorpropham + Silwett	8.33	8.33	9.67	7.00
Chlorpropham + Phase II + Lepton ZC	8.67	9.00	8.00*	9.67
Chlorpropham + Torpedo II	8.33	7.33	9.33	8.33
Hurricane SC + Defy	6.67*	8.00	4.33*	7.33
Hurricane SC + Phase II	6.33*	8.00	4.33*	5.00*
Hurricane SC + Silwett	7.00*	6.67	4.67*	6.67

Treatment	Mean crop damage (0-10)		Mean potato damage (0-10)	
	19 th Jul (Timing C)	15 th Aug (Timing C + 4 weeks)	19 th Jul (Timing C)	15 th Aug (Timing C + 4 weeks)
Hurricane SC + Phase II + Lepton ZC	7.00*	8.00	4.67*	6.63
AHDB 9993 + Defy	6.67*	8.00	6.67*	8.67
AHDB 9993 + Phase II	7.00*	7.33	9.00	8.67
AHDB 9993 + Silwett	7.00*	7.00	9.00	6.67
AHDB 9993 + Phase II + Lepton ZC	7.67	6.33*	9.00	8.00
AHDB 9981 + Defy	6.67*	5.67*	9.00	7.67
AHDB 9981 + Phase II	7.33	6.00*	6.67*	9.33
AHDB 9981 + Silwett	7.67*	7.33	9.33	7.33
AHDB 9981 + Phase II + Lepton ZC	8.67	7.67	9.33	8.33
p value	<0.001	0.042	<0.001	0.058
d.f.	39	39	38	37
L.S.D.	0.9171	1.972	1.431	2.223

Conclusions

- Hurricane + Phase II had a moderate and persistent effect on the volunteer potatoes, causing white blotches and a check to the growth.
- Smaller and younger potatoes were more severely affected than those which were at rosette stage at the first application.
- There was significant crop damage in the plots where Hurricane SC, AHDB 9993 or AHDB 9981 were applied, and these effects persisted until two weeks after application.
- The chosen herbicide had a greater effect on the potatoes than the choice of adjuvant, though Phase II increased the herbicides' effects slightly.

Take home message:

When applied post-emergence, Hurricane SC has potential to cause moderate bleaching and a check to volunteer potato growth, but it did not kill any potatoes.

Objectives

To compare a number of herbicide tank-mixes—and herbicide and adjuvant mixes—applied at three repeated post-emergence application timings with the commercial standard (linuron + prosulfocarb), for selectivity (crop safety) and efficacy of control of volunteer potatoes 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
PP 1/099(3)	Weeds in root vegetables	One (<i>see below</i>)
PP 1/135(3)	Phytotoxicity assessment	None
PP 1/152(3)	Design and analysis of efficacy evaluation trials	None
PP 1/181(3)	Conduct and reporting of efficacy evaluation trials including good experimental practice	None
PP 1/214 (3)	Principles of acceptable efficacy	None
PP 1/224 (2)	Principles of efficacy evaluation for minor uses	None
PP 1/225 (2)	Minimum effective dose	None

There was one deviation 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.

Test site

Item	Details
Location address	Field: off Fordham Rd Freckenham Bury Saint Edmunds IP28 8JB Grid reference: TL659722
Crop	Parsnip
Cultivar	Javelin
Soil or substrate type	Freely draining lime-rich loamy soils
Agronomic practice	See Appendix A
Prior history of site	See Appendix A

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: (m ²)	16 m ²
Number of plants per plot:	N/K
<i>Leaf Wall Area calculations</i>	N/A

Treatment details

AHDB Code	Product name	Active substance	Formulation batch number	Content of active substance (g/L)	Formulation type
AHDB 9993	N/D	N/D	N/D	N/D	N/D
AHDB 9999	N/D	N/D	N/D	N/D	N/D
N/A	Hurricane SC	diflufenican	17088236	500	Suspension Concentrate
chlorpropham	Intruder	chlorpropham	543 H	400	Emulsifiable Concentrate
AHDB 9981	N/D	N/D	N/D	N/D	N/D
N/A	Afalon	linuron	14038858	450	Suspension Concentrate
N/A	Phase II	esterified rapeseed oil	N/K	842	Emulsifiable Concentrate
N/A	Silwet	polyalkylene oxide modified heptamethyl trisiloxane + allyloxy polyethylene glycol methyl ether	N/K	80% w/w 20% w/w	Organosilicone non-ionic wetter
N/A	Lepton ZC	Zinc complex	N/K	-	Nutrient
N/A	Torpedo II	alkoxylated tallow amine + alcohol ethoxylates + natural fatty acids + polyalkylene glycol	N/K	(g/kg) 210 380 75 210	Emulsifiable Concentrate

Application schedule

Trt. No.	Treatment: product name or AHDB code	Rate of active substance(s) (g/ha)	Rate of product (L/ha)
1	Untreated	-	-
2	Untreated	-	-
*3	Afalon + AHDB 9999	225 1600	0.5 2.0
4	chlorpropham + AHDB 9999	720 1600	1.8 2.0
5	chlorpropham + Phase II	720 842	1.8 1.0
6	chlorpropham + Silwett	720 80 20	1.8 0.1 0.1
7	chlorpropham + Phase II + Lepton ZC	720 842 N/K	1.8 1.0 2.4
8	chlorpropham + Torpedo II	720 42 76 15 42	1.8 0.2
9	Hurricane SC + AHDB 9999	50 1600	0.1 2.0
10	Hurricane SC + Phase II	50 842	0.1 1.0
11	Hurricane SC + Silwett	50 80 20	0.1 0.1 0.1

12	Hurricane SC +	50	0.1
	Phase II +	842	1.0
	Lepton ZC	N/K	2.4
13	AHDB 9993 +	160	1.0
	AHDB 9999	1600	2.0
14	AHDB 9993 +	160	1.0
	Phase II	842	1.0
15	AHDB 9993 + Silwett	160	
		80	1.0
		20	0.1
16	AHDB 9993 + Phase II + Lepton ZC	160	1.0
		842	1.0
		N/K	2.4
17	AHDB 9981 + AHDB 9999	112.5	0.25
		1600	2.0
18	AHDB 9981 + Phase II	112.5	0.25
		842	1.0
19	AHDB 9981 + Silwett	112.5	
		80	0.25
		20	0.1
20	AHDB 9981 + Phase II + Lepton ZC	112.5	0.25
		842	1.0
		N/K	2.4

* grower/commercial standard - 2018

Application details – Site 1

	Application A	Application B	Application C
Application date	22/06/2018	03/07/2018	19/07/2018
Time of day	11:30 – 12:50	12:30 – 16:20	11:20 – 12:45
Crop growth stage (average, BBCH)	BBCH 12 (2 leaves) Potato – BBCH 15, small rosette	BBCH 13 (3 leaves) Potato – BBCH 31-59, start of stem elongation to first flower	BBCH 14 (4 leaves) Potato – BBCH 59, first flower
Crop height (cm)	3	7	20
Crop coverage (%)	15	20	30
Application Method	spray	spray	spray
Application Placement	foliar	foliar	foliar
Application equipment	Oxford Precision Sprayer (knapsack)	Oxford Precision Sprayer (knapsack)	Oxford Precision Sprayer (knapsack)
Nozzle pressure (bar)	2.4	2.4	2.4
Nozzle type	Flat fan	Flat fan	Flat fan
Nozzle size	02 F110	02 F110	02 F110
Application water volume/ha	200	200	200
Temperature of air - shade (°C)	23.2 – 26.6	26.1 – 27.0	24.6 – 28.6
Relative humidity (%)	34.4 – 42.5	42.8 – 44.2	35.4 – 44.6
Wind speed range (mph)	4.9 – 9.1	5.6 – 6.1	3.6 – 4.2
Dew presence (Y/N)	N	N	N
Temperature of soil - 10 cm (°C)	23.0	N/K	N/K
Wetness of soil - 2-5 cm	dry	dry	dry
Cloud cover (%)	5	0	95

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

The assessment was for effects on potatoes, so numbers of potatoes were only counted at the start of the experiment, and again after all potatoes were estimated to have established.

Common name	Scientific Name	EPPO Code	Infection level at start of assessment period (0 weeks)	Infection level at middle of assessment period (2 weeks)
Potato	<i>Solanum tuberosum</i>	SOLTU	6.5 (mean no. potatoes per plot)	8.5 (mean no. potatoes per plot)

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)
22/06/2018	0	12	plant counts	Crop population count, potato count
03/07/2018	11	13	plant counts, phytotox	Crop population count, potato count Crop and potato phytotoxicity (scale 0-10, 0 = dead)
19/07/2018	27	14	phytotox	Crop and potato phytotoxicity (scale 0-10, 0 = dead)
02/08/2018	41	43	phytotox	Crop and potato phytotoxicity (scale 0-10, 0 = dead)
15/08/2018	54	46	phytotox	Crop and potato phytotoxicity (scale 0-10, 0 = dead)
12/09/2018	82	48	phytotox	Crop and potato phytotoxicity (scale 0-10, 0 = dead)

* DA – days after application

Statistical analysis

The trial had a randomised block design, with each treatment replicated three times. The trial comprised twenty treatments, including two untreated controls and a grower standard treatment.

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

Results

Plant population - parsnips

There were no significant differences in plant population between the treatments at either assessment.

Table 2. Plant population, at two dates; first assessment just before the first application, and the second at the second post-emergence application.

Treatment	Plant population counts (plants/m/single row) (counts are from a single row of the central double row)	
	22 nd Jun	3 rd Jul
Untreated*	22.75	20.00
Afalon + Defy	21.67	22.50
Chlorpropham + Defy	23.33	23.67
Chlorpropham + Phase II	20.50	17.17
Chlorpropham + Silwett	21.17	19.33
Chlorpropham + Phase II + Lepton ZC	19.17	20.50
Chlorpropham + Torpedo II	20.83	19.33
Hurricane SC + Defy	21.83	21.67
Hurricane SC + Phase II	23.67	20.67
Hurricane SC + Silwett	23.17	19.33
Hurricane SC + Phase II + Lepton ZC	21.50	20.17
AHDB 9993 + Defy	19.67	17.50
AHDB 9993 + Phase II	21.50	18.50
AHDB 9993 + Silwett	22.67	19.00
AHDB 9993 + Phase II + Lepton ZC	22.67	16.67
AHDB 9981 + Defy	20.33	19.50
AHDB 9981 + Phase II	23.33	21.83
AHDB 9981 + Silwett	22.33	18.67
AHDB 9981 + Phase II + Lepton ZC	21.17	18.67
F prob. value	0.329	0.125
d.f.	39	39
L.S.D.	2.999	3.601

* treatments 1 and 2

Plant population – potatoes

The volunteer potatoes occurred naturally and were at varying growth stages when the treatments were applied. There were no significant differences between numbers of potatoes per plot at this stage, and therefore there was an even distribution of potatoes across the trial. At the 2nd application, only three treatments showed a very slight reduction in the number of potatoes; these were Chlorpropham + Phase II + Lepton ZC, Hurricane SC + Phase II, and Hurricane + Phase II + Lepton ZC. However, these were not significant differences. No further potato plant deaths were seen at the subsequent efficacy assessments.

Table 3. Potato counts; bold figures indicate a reduction in potatoes.

Treatment	Mean potato counts per plot		Difference between count 1 and 2
	22 nd Jun	3 rd Jul	
Untreated	6.50	8.50	+2.0
Afalon + Defy	8.00	9.00	+1.0
Chlorpropham + Defy	10.33	12.67	+2.4
Chlorpropham + Phase II	14.33	14.33	0.0
Chlorpropham + Silwett	5.33	6.00	+0.7
Chlorpropham + Phase II + Lepton ZC	5.67	5.00	-0.7
Chlorpropham + Torpedo II	7.00	7.00	0.0
Hurricane SC + Defy	6.00	6.67	+0.7
Hurricane SC + Phase II	13.33	11.33	-2.0
Hurricane SC + Silwett	8.67	9.33	0.7
Hurricane SC + Phase II + Lepton ZC	9.00	8.67	-0.3
AHDB 9993 + Defy	12.33	15.33	+3.0
AHDB 9993 + Phase II	8.00	8.33	+0.3
AHDB 9993 + Silwett	18.33	17.67	+0.6
AHDB 9993 + Phase II + Lepton ZC	10.67	12.00	+1.3.
AHDB 9981 + Defy	12.67	14.33	+1.6
AHDB 9981 + Phase II	8.67	10.33	+1.6
AHDB 9981 + Silwett	9.00	12.00	+3.0
AHDB 9981 + Phase II + Lepton ZC	9.33	10.00	+0.6
F prob. value	0.047	0.162	-
d.f.	39	39	-
L.S.D.	6.161	7.039	-

Phytotoxicity

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.

Crop phytotoxicity

The results of crop phytotoxicity assessments from four dates are presented in Table 4 and Figure 1. These were scored on a scale of 0 to 10, with 0 being dead, and 10 being no phytotoxic effect. Those treatments scored at 8 or above were deemed to have commercially acceptable levels of crop effect, if any.

There was significant crop damage in the plots where Hurricane SC, AHDB 9993 or AHDB 9981 were applied, and these effects persisted until two weeks after application (*see appendix for photos*). Hurricane SC caused bleaching and whitening in spots and blotches to the parsnip leaves, AHDB 9993 caused a diffuse yellowing on the leaves that were present at application, and AHDB 9981 caused yellow patches, and scorch to leaf edges when mixed with Defy or any of the adjuvants. However, there was no crop death. Chlorpropham was the safest treatment, causing very little effect.

The yellowing from AHDB 9981 persisted the longest; at four weeks after application, AHDB9981 mixed with Defy and Phase II still gave significantly lower (damaging) phytotoxicity scores than the untreated. The other treatment which also had significantly persistent phytotoxicity scores at four weeks after application was AHDB 9993 + Phase II + Lepton ZC.

The previously used standard, Afalon + Defy, caused yellow edges and a little stunting during the period of application, but the crop recovered quickly and showed no symptoms at four weeks after application.

Table 4. Mean phytotoxicity scores at four dates throughout assessment period. Values which are significantly different to untreated are starred. Values <8 are deemed commercially unacceptable and are marked in **bold**. * = significantly different

Treatment	Mean crop damage scores			
	3 rd Jul (Timing B)	19 th Jul (Timing C)	2 nd Aug (Timing C + 2 weeks)	15 th Aug (Timing C + 4 weeks)
Untreated*	9.17	8.17	9.00	8.33
Afalon + Defy	7.00*	8.33	8.67	10.00
Chlorpropham + Defy	9.33	8.67	9.00	9.00
Chlorpropham + Phase II	9.00	8.33	9.33	6.67
Chlorpropham + Silwett	8.33	8.33	9.00	8.33
Chlorpropham + Phase II +	8.67	8.67	9.33	9.00

Treatment	Mean crop damage scores			
	3 rd Jul (Timing B)	19 th Jul (Timing C)	2 nd Aug (Timing C + 2 weeks)	15 th Aug (Timing C + 4 weeks)
Lepton ZC				
Chlorpropham + Torpedo II	9.33	8.33	9.00	7.33
Hurricane SC + Defy	6.33*	6.67*	6.67*	8.00
Hurricane SC + Phase II	6.00*	6.33*	7.33*	8.00
Hurricane SC + Silwett	7.33*	7.00*	7.67*	6.67
Hurricane SC + Phase II + Lepton ZC	7.33*	7.00*	6.67*	8.00
AHDB 9993 + Defy	6.00*	6.67*	7.00*	8.00
AHDB 9993 + Phase II	7.67*	7.00*	7.67*	7.33
AHDB 9993 + Silwett	7.33*	7.00*	8.00*	7.00
AHDB 9993 + Phase II + Lepton ZC	8.67	7.67	8.67	6.33*
AHDB 9981 + Defy	6.00*	6.67*	7.67*	5.67*
AHDB 9981 + Phase II	6.33*	7.33	7.67*	6.00*
AHDB 9981 + Silwett	7.33*	7.67*	8.00*	7.33
AHDB 9981 + Phase II + Lepton ZC	8.67	8.67	9.33	7.67
F prob. value	<0.001	<0.001	<0.001	0.042
d.f.	39	39	39	39
L.S.D.	1.0087	0.9171	0.9762	1.972

* treatments 1 and 2

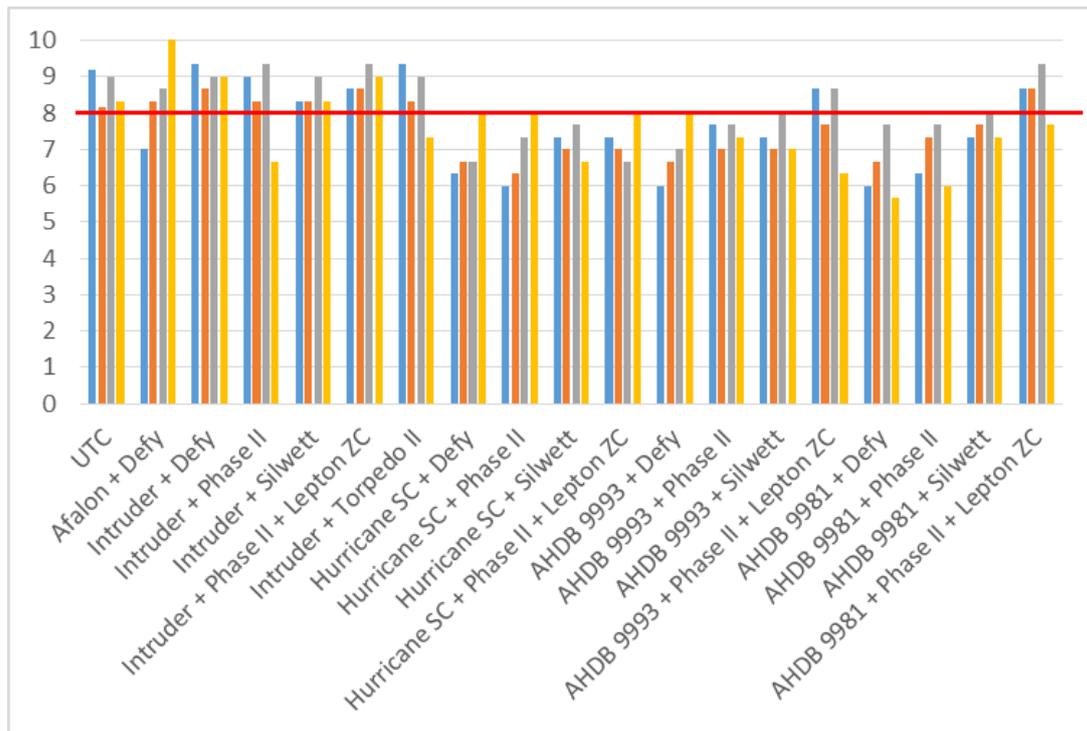


Figure 1. Mean crop phytotoxicity (0-10) at four assessment dates throughout the trial. Scores of ≥ 8 (marked by red line) deemed acceptable damage.

Potato phytotoxicity

The results of potato phytotoxicity assessments from four dates are presented in Table 5 and Figure 2. These were scored on a scale of 0 to 10, with 0 being dead, and 10 being no effect. Scores of 6 or below indicated products where there is promise for control of volunteer potatoes, with these treatments having a moderate to severe effect on the potatoes.

Significant effects on potatoes were seen for seven treatments by the third and final application—these were; all treatment combinations where Hurricane SC was included, chlorpropham + Phase II + Lepton ZC, AHDB 9993 + Defy, and AHDB 9981 + Phase II. However, only one treatment—Hurricane SC + Phase II—showed effects which persisted to the end of the assessment period, four weeks after the final application. Moderate effects developed from chlorpropham + Phase II were first observed at the assessment four weeks after application; these were not noted earlier as were likely senescence due to early blight symptoms rather than a treatment effect. The assessment at eight weeks after application is not shown as blight effects confounded the results.

The commercial standard Afalon + Defy only had a slight effect on the volunteer potatoes, but did severely scorch the black bindweed.

Table 5. Mean phytotoxicity scores at four dates throughout the assessment period. Values which ≤ 6 were deemed a moderate effect and are marked in **bold**. * = significantly different

Treatment	Mean potato damage scores			
	3 rd Jul (Timing B)	19 th Jul (Timing C)	2 nd Aug (Timing C + 2 weeks)	15 th Aug (Timing C + 4 weeks)
Untreated*	9.77	9.78	9.75	8.45
Afalon + Defy	8.00*	8.33*	8.67	8.00
Chlorpropham + Defy	10.00	9.33	9.33	6.33
Chlorpropham + Phase II	9.33	9.33	9.33	6.00*
Chlorpropham + Silwett	9.67	9.67	9.67	7.00
Chlorpropham + Phase II + Lepton ZC	9.33	8.00*	9.33	9.67
Chlorpropham + Torpedo II	10.00	9.33	9.67	8.33
Hurricane SC + Defy	6.00	4.33*	4.67*	7.33
Hurricane SC + Phase II	6.00*	4.33*	5.00*	5.00*
Hurricane SC + Silwett	7.67*	4.67*	5.33*	6.67
Hurricane SC + Phase II + Lepton ZC	7.00*	4.67*	5.67*	6.63
AHDB 9993 + Defy	8.33*	6.67*	7.00*	8.67
AHDB 9993 + Phase II	9.00	9.00	8.67	8.67
AHDB 9993 + Silwett	9.67	9.00	9.67	6.67
AHDB 9993 + Phase II + Lepton ZC	10.00	9.00	9.33	8.00
AHDB 9981 + Defy	10.00	9.00	9.00	7.67
AHDB 9981 + Phase II	9.00	6.67*	7.67*	9.33
AHDB 9981 + Silwett	9.67	9.33	9.33	7.33
AHDB 9981 + Phase II + Lepton ZC	9.67	9.33	9.33	8.33
F prob. value	<0.001	<0.001	<0.001	0.058
d.f.	38	38	38	37
L.S.D.	0.7833	1.431	1.619	2.223

* treatments 1 and 2

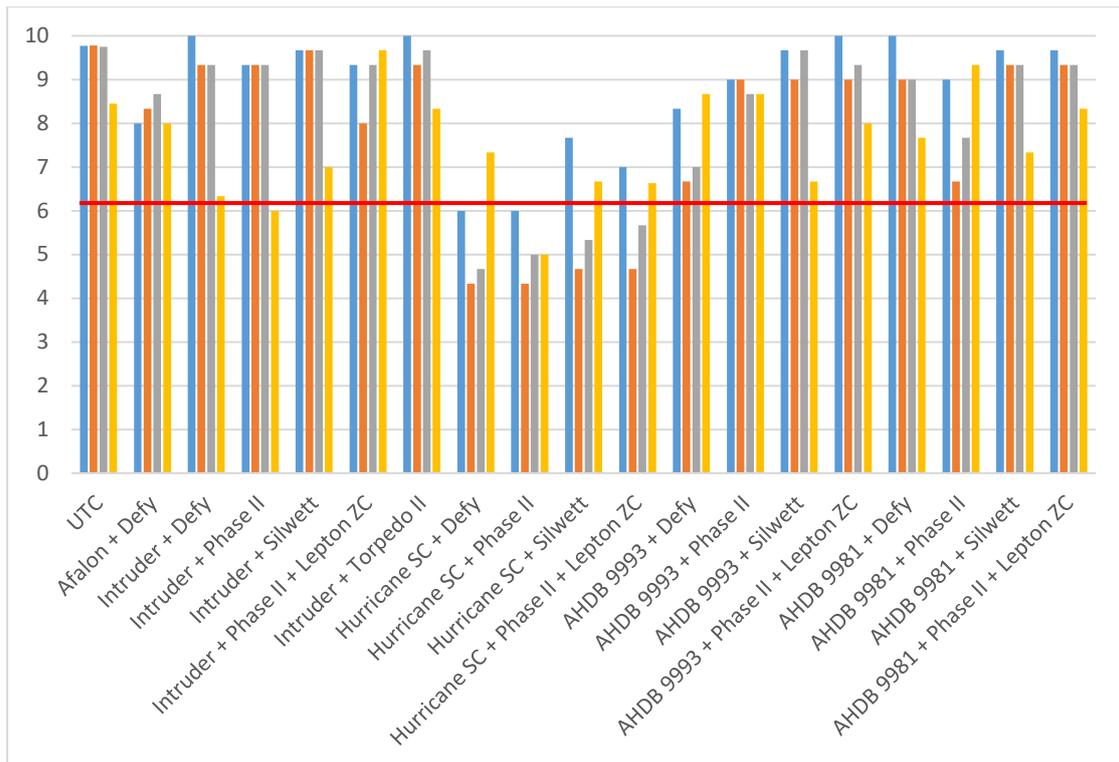


Figure 2. Mean phytotoxicity (0-10) at four assessment dates throughout the trial. Scores of ≤ 6 (marked by red line) indicate moderate to severe effects on the potato plants.

Discussion

Identifying alternative treatments for the control of volunteer potatoes is a challenge, as those products and treatment combinations with the potential to severely reduce growth or killing potatoes tend to also be on the borderline of crop safety for parsnips or carrots. Afalon + Defy was the safe commercial standard before linuron's revocation in 2018, but this treatment could also be unpredictable in its efficacy, and in this trial it did not have a great effect on the volunteer potatoes, despite controlling most of the weeds.

The volunteer potatoes occurred naturally and were at varying growth stages when the treatments were applied. There were no significant differences between numbers of potatoes per plot, and therefore an even distribution of potatoes across the trial. At the 2nd application, there were only three treatments where a very slight—but not significant—reduction in the number of potatoes was seen; these were, chlorpropham + Phase II (esterified rape seed oil) + Lepton ZC, Hurricane SC + Phase II, and Hurricane + Phase II + Lepton ZC with 0.3 to 2.0 fewer potatoes counted in the final population assessment. Despite these reductions in potato numbers, no further potato plant deaths were seen at subsequent efficacy assessments, and there were no significant differences between the potato numbers in the second population count.

Significant effects on potatoes were seen from seven treatments by the third and final application; these were, all treatment combinations where Hurricane SC was included, chlorpropham + Phase II + Lepton ZC, AHDB 9993 + Defy, and AHDB 9981 + Phase II. However, the observed effects only persisted to the end of the assessment period (at four weeks after the final application) in one treatment—Hurricane SC + Phase II. The moderate effects seen following treatment with chlorpropham + Phase II were first noted four weeks after application, but were not seen in earlier assessments; this was likely due to senescence—an early symptom of blight—rather than a treatment effect.

There was significant crop damage in the plots where Hurricane SC, AHDB 9993 or AHDB 9981 were applied, and these effects persisted until two weeks after application (*see appendix for photos*). Hurricane SC caused bleaching and whitening in spots and blotches to the parsnip leaves, AHDB 9993 caused a diffuse yellowing on the leaves that were present at application, and AHDB 9981 caused yellow patches, and scorch to leaf edges when mixed with Defy or any of the adjuvants. However, there was no crop death. Chlorpropham was the safest treatment, causing very little effect.

The yellowing from AHDB 9981 persisted the longest; at four weeks after application, AHDB9981 mixed with Defy and Phase II still gave significantly lower (damaging) phytotoxicity scores than the untreated. The other treatment which also had significantly persistent phytotoxicity scores at four weeks after application was AHDB 9993 + Phase II + Lepton ZC.

The previously used standard, Afalon + Defy caused yellow edges and a little stunting during the period of application, but the crop recovered quickly and showed no symptoms at four weeks after application.

Hurricane SC + Phase II shows the greatest potential for volunteer potato control, but it has a very striking effect on the parsnips. However, there was no crop loss from this treatment in the trial. Some of the potatoes were fairly large when the herbicide mixes were first applied and in photos, the new growth can be seen to be unaffected in the large plants. Smaller plants sustained more damage, and therefore timing may be important. The tricky balance is timing the application to be damaging to the potato and not the parsnip, and further work is required with the most promising treatment combinations.

Conclusions

- Hurricane + Phase II had a moderate and persistent effect on the volunteer potatoes, causing white blotches and a check to the growth.
- Smaller and younger potatoes were more severely affected than those which were at rosette stage at the first application.
- There was significant crop damage in the plots where Hurricane SC, AHDB 9993 or AHDB 9981 were applied, and these effects persisted until two weeks after application.
- The chosen herbicide had a greater effect on the potatoes than the choice of adjuvant, though Phase II increased the herbicides' effects slightly.

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 the growers from BCGA who provided sites and crops for the trial, as well as technical input—particularly Jason Ambrose of Tompsett Burgess Growers for hosting the trial.

Appendix

- a. Crop diary – events related to growing crop. – awaiting details

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

Previous cropping

Year	Crop
2017	
2016	
2015	
2014	

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

Date	Product	Rate	Unit

Pesticides applied to trial area

Date	Product	Rate	Unit

Details of irrigation regime

Date	Type, rate and duration	Amount applied (mm)

- b. Trial diary

Site 1

Date	Event
08/05/2018	Crop drilled.
09/05/2018	Farm applied standard pre-emergence.
22/06/2018	First application Trial assessment - Crop population count and potato count.
03/07/2018	Second application Trial assessment - Crop population count and potato count. Crop and potato phytotoxicity.
19/07/2018	Third application Trial assessment - Crop and potato phytotoxicity.

Date	Event
02/08/2018	Trial assessment - Crop and potato phytotoxicity.
15/08/2018	Trial assessment - Crop and potato phytotoxicity.
12/09/2018	Trial assessment - Crop and potato phytotoxicity. Blight also seen in plots, so damage data confounded.

c. Photographs of effects on the crop and potatoes—taken on 3rd July, after the first application.

		
Linuron + Defy (yellow fringe)	Hurricane SC + Defy	Hurricane SC + Phase II (note: smaller potato is not growing through the effects as easily)
		
AHDB9993 + Silwett	AHDB9993 + Silwett	AHDB9981 + Phase II

- d. Climatological data during study period; min. and max. air temperatures, and relative humidity from in-field logger. No rainfall data available for site.

Date	Temp °C (minimum)	Temp °C (maximum)	Mean relative humidity (%)
22/06/2018	7.0	22.0	60.8
23/06/2018	9.5	26.0	60.9
24/06/2018	9.0	27.0	63.5
25/06/2018	11.5	30.0	60.1
26/06/2018	9.5	29.5	60.3
27/06/2018	12.5	28.0	63.9
28/06/2018	10.0	28.0	72.2
29/06/2018	11.5	28.0	70.8
30/06/2018	12.5	29.0	63.1
01/07/2018	11.0	30.0	58.5
02/07/2018	11.5	29.0	54.9
03/07/2018	9.5	26.5	59.9
04/07/2018	10.5	27.5	64.8
05/07/2018	14.5	30.5	62.9
06/07/2018	14.5	28.0	69.8
07/07/2018	16.0	31.0	67.5
08/07/2018	13.0	29.5	65.5
09/07/2018	16.0	29.0	66.5
10/07/2018	13.5	21.0	74.7
11/07/2018	13.5	22.0	80.5
12/07/2018	12.5	23.0	77.7
13/07/2018	10.5	27.5	71.5
14/07/2018	12.5	31.0	66.2
15/07/2018	14.0	34.5	58.7
16/07/2018	14.0	32.0	60.0
17/07/2018	15.5	25.5	62.9
18/07/2018	14.5	29.5	60.9
19/07/2018	15.5	30.5	59.9
20/07/2018	14.5	30.0	62.9
21/07/2018	16.0	31.0	65.9
22/07/2018	15.0	30.0	65.9
23/07/2018	16.0	34.5	63.4
24/07/2018	16.5	33.0	59.4
25/07/2018	16.0	34.0	62.7
26/07/2018	17.5	36.0	61.1
27/07/2018	20.0	32.0	82.6
28/07/2018	16.0	23.5	81.1
29/07/2018	14.5	20.0	94.2
30/07/2018	16.5	24.0	87.8
31/07/2018	16.0	26.0	82.6
01/08/2018	14.0	29.0	77.0
02/08/2018	15.0	32.5	76.4

Date	Temp °C (minimum)	Temp °C (maximum)	Mean relative humidity (%)
03/08/2018	17.5	33.0	79.5
04/08/2018	17.5	27.0	78.9
05/08/2018	15.0	33.0	70.2
06/08/2018	17.0	35.0	65.7
07/08/2018	17.0	33.0	68.0
08/08/2018	17.5	26.5	62.5
09/08/2018	14.0	18.0	89.4
10/08/2018	11.0	17.0	96.2
11/08/2018	9.5	22.5	91.2
12/08/2018	16.0	20.0	94.9
13/08/2018	16.0	21.0	99.0
14/08/2018	14.0	23.0	94.0
15/08/2018	14.5	24.5	89.9
16/08/2018	14.5	18.5	96.0
17/08/2018	11.0	19.5	92.9
18/08/2018	14.5	21.5	93.2
19/08/2018	16.5	22.5	94.4
20/08/2018	16.5	24.0	95.6
21/08/2018	16.5	26.5	91.0
22/08/2018	14.5	24.0	91.6

f. ORETO certificate

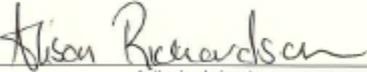


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