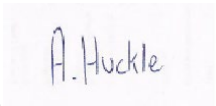
Final Trial Report

Trial code:	2018. SP13
Title:	AHDB SCEPTREplus pumpkin herbicide screen AHDB SCEPTREplus pumpkin inter-row herbicide screen
Crop	Group: field vegetables – Cucurbita (pumpkin)
Target	General broadleaf weeds and grasses, 3WEEDT
Lead researcher:	Angela Huckle
Organisation:	RSK ADAS
Period:	21st May 2018 – 31st March 2019
Report date:	31st March 2019 (delayed to 2nd July 2021)
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

1st July 2021
Date



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Trial Summary

Introduction

There are currently very few herbicide options for weed control for cucurbit growers with only three residual herbicides approved under EAMU for use on the crop. These include isoxaben, propyzamide and, most recently, clomazone which gained approval in 2015 to improve control of groundsel. Wing-P is also approved for inter-row application, but it only offers temporary suppression and can be damaging if not applied with care, such as use of a shielded applicator.

This limited range of herbicides leaves gaps in the weed control spectrum, and growers experience problems with a wide range of weeds. In particular, polygonum weeds, black nightshade, black bindweed, sowthistle, and several grass weeds including annual meadow grass, volunteer cereals (especially barley), wild oat, black-grass and brome are problematic for growers. As well as competing with the crop for nutrients and water, these weeds also hinder pickers reducing harvest efficiency.

Black plastic mulch is commonly used in courgette crops for weed control in the row and occasionally in some pumpkin crops. This is because the crops are very sensitive to herbicides, including those currently approved. Therefore for some growers, it is common practice to apply authorised herbicides via hooded tractor-mounted spray applicators to shield the crop foliage and gain control of weed between the rows. However problems with weed between rows are still experienced as there are weaknesses in the spectrum of weeds controlled by the few currently authorised herbicides as described above. Therefore further options are required inter-row as well as over the row.

The objective of this trial was to identify crop safe and effective herbicides for weed control in pumpkins, aiming to expand the options available to growers.

Method

Trials were sited at a commercial pumpkin grower in Hampshire. The trial field was drilled on 22nd May 2018, with pumpkin variety ‘Racer’.

Trial 1 (over-row):
Treatments were applied at four timings – pre-drilling (21/05/2018); post-drilling but pre-emergence (22/05/2018); post-emergence at five true leaves (13/06/2018); and post-emergence, 5 weeks after drilling (26/06/2018). All were applied with a 1.5 m boom, using an Oxford Precision Sprayer knapsack at 200 L/ha water volume. The treatments applied pre-drilling were incorporated to a depth of approximately 20 cm using a small rotovator. A randomised block design was used with four replicates of 22 treatments, including two untreated controls and a grower standard pre-emergence treatment (propyzamide OR isoxaben + clomazone). There were 88 plots in total, each 1.65 m x 6 m.

Trial 2 (inter-row):
Treatments were applied at three timings – post-drilling but pre-emergence (22/05/2018); post-emergence at five true leaves (13/06/2018); and post-emergence at 5 weeks after drilling (26/06/2018). All were applied with a lance (spray width 0.5 m), using an Oxford Precision sprayer knapsack at 200 L/ha water volume. A randomised block design was used with four replicates of nine treatments, including an untreated control and a grower standard treatment (diquat). There were thirty-six plots in total, each 3.3 m x 4 m.

Both trials were assessed on four occasions, focusing on weed ground cover (i.e. treatment efficacy) and crop phytotoxicity (i.e. treatment safety). Assessments were carried out three, five, seven and nine weeks after the first treatment was applied.

Results and discussion

The main weeds present in both trials were fat-hen, chickweed, redshank and small nettle, smaller populations of mayweed, field pansy, black nightshade and barnyard grass were also present.

Trial 1

Treatments which were both crop safe, or close to being crop safe and significantly reduced weed levels compared to the untreated included pre-emergence treatments; Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha, Bonalan 8 L/ha, AHDB 9898, AHDB 9994 and AHDB 9917. Only Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha was crop safe post-emergence, but AHDB 9987 + Gamit 35 CS 0.25 L/ha was near to crop safe and no plant losses were observed. This would be worth revisiting as it has been safely applied over cucurbits in previous trials in SCEPTRE, and there are very few herbicides which are safe to use post-emergence in pumpkins. AHDB 9898 was the only treatment to significantly reduce total mean weed cover at every assessment as well as having crop safe phytotoxicity scores at every assessment. The reduction in weed levels was not one of the best performing, but it would be a useful addition for tank-mixing and would improve fat-hen control.

There were several treatments which scored just below a commercially acceptable level mainly due to slight stunting, but pumpkins still developed and the following would be worth considering further, as they offer useful weed control of either general weeds, or selected problem weeds such as grasses. These treatments were Bonalan 8.0 L/ha, AHDB 9917 and AHDB 9994 applied pre-emergence, as well as AHDB 9985 and AHDB 9987 applied either alone or with Gamit 36 CS post-emergence. AHDB 9985 caused transient yellowing. AHDB 9985 is a graminicide and would improve control of grasses. AHDB 9985 didn't significantly reduce weeds in this trial as mainly broad-leaved weeds were present. However, authorisation would still be useful for growers to improve control of grass weeds.

AHDB 9952, and Wing-P applied pre-emergence caused severe stunting and distortion, while AHDB 9994 applied post-emergence severely scorched the plants and therefore these products are not safe to use in pumpkins at these timings (See appendix for photos).

Trial 2

Shark 0.3 L/ha and Finalsan 34 L/ha + Activator 90 0.2 L/ha applied inter-row with a hooded applicator were crop safe throughout the entire trial period. All treatments were crop safe or very close to safe by the trial conclusion on 24th July (Table 2). There were some transient effects soon after application where Wing-P was applied. In these plots, the crop was stunted and exhibited distorted growth for up to a month after application. The pumpkins grew through this, but did remain a growth stage behind the other plots. The other crop effects were scorch to the edges of leaves where they were caught by the desiccant sprays. Again this was a transient effect, from which the pumpkins recovered from quickly.

All treatments significantly reduced percentage weed cover in the outside row – the inter-row treated area - at all dates throughout the duration of the trial assessment period (Table 7 and 8). In addition, Finalsan + Activator 90 applied twice, and Wing-P 4 L/ha applied pre-emergence, significantly reduced weed levels within the crop row by up to 19.3%. Wing-P is likely to have moved into the crop row to cause the extra weed reduction outside the area where the product was applied. The increased efficacy of the Finalsan treatment is unexpected.

The best performing treatment was AHDB 9897 + Phase II with the lowest weed cover in the outside row, at only 10.6% mean weed cover by the trial conclusion, therefore was the most effective in terms of weed cover reduction. This is followed closely by 'Shark', which also showed consistently low weed cover relative to the other treatments. Finalsan 34 L/ha + Activator 90 0.2 L/ha performed equivalent to the commercial standard in 2018 of diquat 2.0 L/ha.

Table 1. Summary of crop damage (27th July 2018, 12 weeks post-treatment) and percentage weed cover at the final trial assessment of Trial 1. Figures in **bold** are significantly different to the untreated. Weed cover data is transformed. Figures in red are below commercially acceptable levels of damage

Treatment	Timing	Crop damage (0-10)	Mean weed cover (%)	
			Angular	Back-transformation
Untreated	-	8.4	79.9	96.9
Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha	B	8.0	**51.3**	**60.8**
Kerb Flo 1.875 L/ha	B	8.0	77.9	95.6
Bonalan 8.0 L/ha	A	7.5	**60.6**	**75.9**
AHDB 9952	A	7.3	**26.5**	**19.9**
AHDB 9995	B	8.0	81.1	97.6
AHDB 9987	B	8.5	67.5	85.4
AHDB 9987 + Gamit 36 CS 0.25 L/ha	B	8.0	**33.1**	**29.7**
AHDB 9918	B	7.7	72.2	90.6
AHDB 9898	B	8.0	**64.4**	**81.3**
WING-P	B	7.0	**46.4**	**52.5**
AHDB 9998	B	8.0	75.8	94.1
WING-P + AHDB 9998	B	7.0	**45.7**	**51.3**
AHDB 9994	B	8.0	**49.3**	**57.5**
AHDB 9917	B	7.5	**59.8**	**74.7**
Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha	C	8.0	81.1	97.6
AHDB 9987	C	7.5	77.3	95.2
AHDB 9987 + Gamit 36 CS 0.25 L/ha	C	7.5	67.8	85.8
AHDB 9994	C	7.4	**43.8**	**47.8**
Diquat, then AHDB 9985	C D	7.7	83.6	98.8
Diquat, then AHDB 9985	C D	7.5	84.3	99.0
p value		0.996	<.001	
d.f.		64	20	
L.S.D.		1.313	11.36	

Table 2. Summary of crop damage (27th July 2019, 12 weeks after pre-emergence treatment) and percentage weed cover at the final trial assessment of Trial 2. Figures in **bold** are significantly different to the untreated. Weed cover data is transformed. Figures in red are below commercially acceptable levels of damage

Treatment	Crop damage (0-10)	Mean weed cover (%) In between pumpkin rows	
		Angular	Back-transformation
Untreated	10.0	82.5	98.28
Diquat 2.0 L/ha	8.5	**53.7**	**65.01**
Shark 0.3 L/ha	9.0	**13.2**	**5.25**
AHDB 9897 + Phase II 1.0 L/ha	8.5	**10.6**	**3.36**
Finalsan 34.0 L/ha + Activator 90 0.2 L/ha	8.7	**58.3**	**72.36**
Finalsan 34.0 L/ha + Activator 90 0.2 L/ha applied twice	7.7	**49.6**	**58.01**
Wing-P 4.0 L/ha	8.0	**18.9**	**10.45**
Wing-P 2.0 L/ha	8.3	**25.5**	**18.58**
Wing-P 2.0 L/ha + AHDB 9998	8.5	**20.1**	**11.76**
p value	<0.001	<.001	
d.f.	24	24	
L.S.D.	0.5301	14.22	

Conclusion

Trial 1

- Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha and AHDB9898 applied pre-emergence. were both crop safe throughout the trial and significantly reduced weed cover compared to the untreated control at the final assessment.
- Bonalan 8.0 L/ha, AHDB 9994, AHDB 9917 and AHDB 9987 + Gamit 36 CS 0.25 L/ha significantly reduced weed levels and were near to crop safe causing on slight stunting or yellowing which was transient.
- AHDB 9987 + Gamit 36 CS 0.25 L/ha could be useful at both pre- and post-emergence application timings.

Trial 2

- All treatments significantly reduced percentage weed cover in the inter-row treated area.
- All treatments were crop safe, except for Finalsan 34.0 L/ha + Activator 90 applied twice, but even this treatment effect was just below the acceptable limit.
- Wing-P caused stunting which persisted until the end of the trial but was deemed acceptable.

Take home message

AHDB 9898, AHDB 9987, AHDB 9994, AHDB 9917 and Bonalan 8.0 L/ha should be considered for authorisation for use in pumpkins to improve weed control. Many of these products were trialled for the first time in 2018 and further work to confirm crop safety in a different season would be recommended.

Inter-row applications of Shark 0.3 L/ha and AHDB 9897 provide better weed control than diquat and should be considered for authorisation. Including Finalsan (EAMU 1609/20) in current herbicide programmes would aid weed control when applied twice and gives equivalent control to diquat.

Objectives

1. Trial 1: to compare a number of pre- and post-drilling applied herbicides with the commercial standards (propyzamide or isoxaben + clomazone pre-emergence) for selectivity (crop safety) and efficacy in pumpkins.
2. Trial 2: to compare a number of pre-emergence and post-emergence herbicides applied as inter-row applications with the commercial standard (diquat) for selectivity (crop safety) and efficacy in pumpkins.

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 site

Item	**Details**
Location address	Field: T1 Barfoots Titchfield PO14 4LN Hampshire Grid reference: SZ 83797 97974
Crop	Pumpkin
Cultivar	Racer
Soil or substrate type	Freely sandy loam soil
Agronomic practice	See Appendix A
Prior history of site	See Appendix A

Trial design

Item	**Details**
Trial design:	Fully randomised block
Number of replicates:	4
Row spacing:	0.85 m (Trial 1, two rows per plot; Trial 2, four rows per plot)
Plot size: (w x l)	1.65 m x 6 m (Trial 1), 3.3 m x 4 m (Trial 2)
Plot size: (m^2)	9.9 m^2 (Trial 1), 13.2 m^2 (Trial 2)
Number of plants per plot:	Approx. 4 per m^2
Leaf Wall Area calculations	N/A

Treatment details

AHDB Code	Product name	Active substance	Formulation batch number	Content of active substance in product (g/L)	Formulation type
N/A	Bonalan	benfluralin	SIPAL7005	150	Emulsifiable Concentrate
N/A	Activator 90	alcohol ethoxylates natural fatty acids	106814	(g/kg) 750 (g/kg) 150	Emulsifiable Concentrate
AHDB 9994	Emerger	aclonifen	EV56006446	600	Suspension Concentrate
AHDB 9898	BAS 656 12H	dimethenamid-p	0014793425	720	Emulsifiable Concentrate
AHDB 9917	BAS 684 03H	cinmethylin	FD-170630-0007	N/K	Emulsifiable Concentrate
AHDB 9985	Centurion Max	clethodim	17FHL109	120	Emulsifiable Concentrate
AHDB 9952	Devrinol	napropamide	1704-20051	450	Suspension Concentrate
AHDB 9998	Dual Gold	s-metalochlor	SMO5D0172	960	Emulsifiable Concentrate
AHDB 9973	Finalsan	pelargonic acid	536515	186.7	Emulsifiable Concentrate
N/A	Flexidor 500	isoxaben	F006H15002	500	Suspension Concentrate
N/A	Gamit 36 CS	clomazone	N/K	360	Capsule suspension
AHDB 9897	Gozai	pyraflufen-ethyl	671982	26.5	Emulsifiable Concentrate
AHDB 9995	Intruder	chlorpropham	543H	400	Emulsifiable Concentrate
N/A	Kerb Flo	propyzamide	F470H66011	400	Suspension concentrate
N/A	Phase II	esterified rapeseed oil	N/K	842	Emulsifiable Concentrate
N/A	Reglone	diquat	711838	200	Soluble Concentrate
N/A	Shark	carfentrazone-ethyl	N/K	60	Micro-emulsion
AHDB 9987	Successor	pethoxamid	N/K	600	Emulsifiable concentrate
AHDB 9918	Sunfire	flufenacet	335185	500	Suspension Concentrate
WING-P	Wing-P	dimethenamid-p + pendimethalin	14243535	212.5 250	Emulsifiable Concentrate

Application schedule

Trial 1:

Trt. No.	Treatment: product name or AHDB code	Application timing code	Rate of active substance(s) (ml/ha)	Rate of product (L/ha)
1	Untreated	-	-	-
2	Untreated	-	-	-
3*	Flexidor 500 + Gamit 36 CS	B	250 90	0.5 0.25
4*	Kerb Flo	B	750	1.875
5	Bonalan	A	1200	8.0
6	AHDB9952	A	1800	4.0
7	AHDB9995	B	800	2.0

Trt. No.	Treatment: product name or AHDB code	Application timing code	Rate of active substance(s) (ml/ha)	Rate of product (L/ha)
8	AHDB9987	B	1200	2.0
9	AHDB9987 + Gamit 36 CS	B	600 90	1.0 0.25
10	AHDB9918	B	240	0.48
11	AHDB9898	B	504	0.7
12	Wing-P	B	425	2.0
13	AHDB9998	B	1344	1.4
14	Wing-P + AHDB9998	B	425, 500 960	2.0 1.0
15	AHDB9994	B	600	1.0
16	AHDB9917	B	N/A	0.7
17	Flexidor 500 + Gamit 36 CS	C	250 90	0.5 0.25
18	AHDB9987	C	1200	2.0
19	AHDB9987 + Gamit 36 CS	C	600 90	1.0 0.25
20	AHDB9994	C	600	1.0
21	Reglone**, Centurion Max	C D	400 120	2.0 1.0
22	Reglone**, Centurion Max	C D	400 180	2.0 1.5

* Grower standards
** Inter-row application

Trial 2:

Trt. No.	Treatment: product name or AHDB code	Application timing code	Rate of active substance(s) (ml/ha)	Rate of product (L/ha)
1	Untreated	-	-	-
2	Reglone	C	400	2.0
3	Shark	C	18	0.3
4	AHDB9897 + Phase II	C	21.2 842	0.8 1.0
5	AHDB9973 + Activator 90	C	6347.8 150, 30	34.0 0.2
6	(AHDB9973 + Activator 90) x2	C, D	6347.8 150, 30	34.0 0.2
7	Wing-P	B	850 1000	4.0
8	Wing-P	B	425 500	2.0
9	Wing-P + AHDB9998	B	425 500 1344	2.0 1.4

Application details

	Timing A	Timing B	Timing C	Timing D
Application date	21/05/2018	22/05/2018	13/06/2018	26/06/2018
Time of day	14:00 – 14:30	9:30 – 11:00	09:00 – 10:30	11:05 – 12:40
Crop growth stage (Max, min average BBCH)	N/A (pre-drill)	00	15	51
Crop height (cm)	N/A	N/A	17	50
Crop coverage (%)	N/A	N/A	12	55
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 bar (trial 1)	2.4 bar (trial 1) 2.5 bar (trial 2)	2.4 bar (trial 1) 2.5 bar (trial 2)	2.4 bar (trial 1) 2.5 bar (trial 2)
Nozzle type	Flat fan	Flat fan	Flat fan	Flat fan
Nozzle size	02F110	02F110	02F110	02F110
Application water volume/ha	200	200	200	200
Temperature of air - shade (°C)	22.9 – 25.0	18.1	18.9 – 20.6	25.3 – 25.4
Relative humidity (%)	52.1 – 55.4	62.4	62.0 – 66.3	47.7 – 64.0
Wind speed range (mph)	4.0 – 4.1	7.9	1.7 – 2.6	6.0 – 6.3
Dew presence (Y/N)	N	N	N	N
Temperature of soil - 10cm (°C)	30.0	17.0	N/K	N/K
Wetness of soil - 2-5 cm	dry	dry	dry	dry
Cloud cover (%)	N/K	45	0	0

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

Trial 1:

Common name	**Scientific Name**	**EPPO Code**	**Weed level at first assessment** (3 weeks)	**Weed level mid-assessment period** (5 weeks)	**Weed level at end of assessment period** (9 weeks)
Broad leaved weeds and grasses	*N/A*	3WEEDT	29.1% *(untreated average)*	92.9% *(untreated average)*	96.1% *(untreated average)*

Trial 2:

Common name	Scientific Name	EPPO Code	Weed level at first assessment (3 weeks)	Weed level mid-assessment period (7 weeks)	Weed level at end of assessment period (9 weeks)
Broad leaved weeds and grasses	*N/A*	3WEEDT	37.2% *(untreated average)*	78.4% *(untreated average)*	86.4% *(untreated average)*

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)
08/06/2018	19	12	efficacy, phytotox	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover – whole plot score
26/06/2018	37	51	efficacy, phytotox	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover – whole plot score
10/07/2018	51	62	efficacy, phytotox	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover – whole plot score
24/07/2018	65	64	efficacy, phytotox	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover – whole plot score

* DA – days after application A

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)
12/06/2018	22	13	efficacy, phytotox	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover – inside and outside row
26/06/2018	36	51	efficacy, phytotox	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover – inside and outside row
10/07/2018	50	62	efficacy, phytotox	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover – inside and outside row
24/07/2018	64	64	efficacy, phytotox	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover – inside and outside row

* DA – days after application A

Statistical analysis

Both trials had randomised block designs, each with treatments replicated four times.

All data were analysed by ANOVA using Genstat 18.4 by Chris Dyer at RSK ADAS.

As the distribution of weeds was uneven across the 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.

Results – Trial 1

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

Phytotoxicity was recorded using the following scale:

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

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

Pumpkins are sensitive to many herbicides, and only three products were crop safe throughout the entire trial assessment period. These were Kerb Flo 1.875 L/ha, AHDB 9898 and AHDB 9998 when applied pre-emergence.

Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha, AHDB 9995, AHDB 9987, AHDB 9987 + Gamit 36 CS 0.25 L/ha, and AHDB 9994 applied pre-emergence, and Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha applied post-emergence all exhibited transient crop damage early after application, with mean crop damage scores below the acceptable threshold of 8, but were crop safe by the trial end. The early crop damage was exhibited either as stunting or chlorosis of leaf edges.

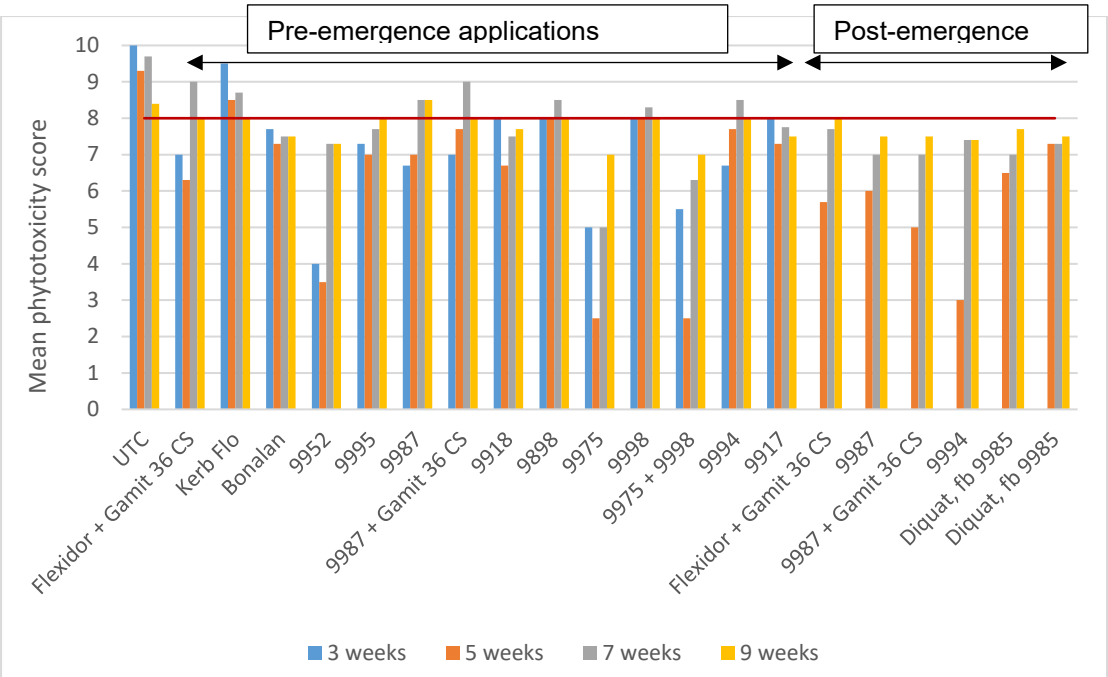
There were several treatments which scored just under a commercially acceptable level mainly due to slight stunting, but pumpkins still developed and therefore these may be worth considering further, if they offer useful weed control. These treatments were Bonalan 8.0 L/ha, AHDB 9918, and AHDB 9917 applied pre-emergence, as well as AHDB 9985 and AHDB 9987 applied either alone or with Gamit 36 CS post-emergence. AHDB 9985 caused transient yellowing.

AHDB 9952, and Wing-P applied pre-emergence caused severe stunting and distortion, while AHDB 9994 applied post-emergence severely scorched the plants and therefore these products are not safe to use in pumpkins at these timings.

Table 3. Mean phytotoxicity scores at four dates throughout the trial period (0 to 10; 0 = complete crop death, 10 = no damage). Scores ≥8 deemed commercially acceptable damage, those <8 (unacceptable damage) are highlighted in red. Application timings: A – pre-emergence and incorporated (21st May), B – pre-emergence (22nd May), C – post-emergence -5 true leaves (13th June), D – post-emergence (flower bud) (26th June).

Treatment	Application timing	Mean crop damage scores			
		8th June	26th June	10th July	24th July
Untreated	-	10.0	9.3	9.7	8.4
Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha	B	7.0	6.3	9.0	8.0
Kerb Flo 1.875 L/ha	B	9.5	8.5	8.7	8.0
Bonalan 8.0 L/ha	A	7.7	7.3	7.5	7.5
AHDB 9952	A	4.0	3.5	7.3	7.3
AHDB 9995	B	7.3	7.0	7.7	8.0
AHDB 9987	B	6.7	7.0	8.5	8.5
AHDB 9987 + Gamit 36 CS 0.25 L/ha	B	7.0	7.7	9.0	8.0
AHDB 9918	B	8.0	6.7	7.5	7.7
AHDB 9898	B	8.0	8.0	8.5	8.0
WING-P	B	5.0	2.5	5.0	7.0
AHDB 9998	B	8.0	8.0	8.3	8.0
WING-P + AHDB 9998	B	5.5	2.5	6.3	7.0
AHDB 9994	B	6.7	7.7	8.5	8.0
AHDB 9917	B	8.0	7.3	7.75	7.5
Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha	C	-	5.7	7.7	8.0
AHDB 9987	C	-	6.0	7.0	7.5
AHDB 9987 + Gamit 36 CS 0.25 L/ha	C	-	5.0	7.0	7.5
AHDB 9994	C	-	3.0	7.4	7.4
Diquat 2.0 L/ha, then AHDB 9985	C D	-	6.5	7.0	7.7
Diquat 2.0 L/ha, then AHDB 9985	C D	-	7.3	7.3	7.5
F pr. value		<0.001	<0.001	<0.001	0.996
d.f.		46	64	64	64
L.S.D.		0.9755	1.423	1.1018	1.313

Figure 1. Mean phytotoxicity (0-10) at three, five, seven and nine weeks after treatment application. Scores of 8 or above deemed 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 4 and Figure 3. The percent reduction in weed cover compared to the untreated control was calculated from these figures (using Abbotts formula), and results for each treatment are listed in Table 5.

Treatments which resulted in significantly reduced mean weed cover compared to the control by the end of the trial assessment period on 24th July are Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha, Bonalan, AHDB 9952, AHDB 9987 + Gamit 36 CS 0.25 L/ha, AHDB 9898, WING-P, AHDB 9994, AHDB 9917 and WING-P + AHDB 9998 applied pre-emergence. AHDB 9994 was the only product to significantly reduce weed cover when applied post-emergence. By the trial end on 24th July, the programmes which performed the best with the lowest mean weed cover were in plots treated with AHDB 9952 and AHDB 9987 + Gamit 36 CS 0.25 L/ha applied at a pre-emergence timing (Figure 3).

Flexidor + Gamit 36 CS, AHDB 9987, AHDB 9987 + Gamit 36 CS, and AHDB 9985 applied post-emergence showed no significant difference in weed cover to the untreated control at any point during the trial (Table 4). However it should be considered that AHDB 9918 and AHDB 9985 were included in the screen because of their activity on grass weeds, and therefore would not be expected to perform well on control of the mainly broad leaved weeds present in the trial area.

The weeds present were mainly fat-hen, chickweed, redshank and small nettle. Smaller populations of mayweed, field pansy, black nightshade and barnyard grass were also present.

Table 4. Mean percentage weed cover values (transformed), values in bold are significantly different from the UTC. Application timings: A – pre-emergence and incorporated (21st May), B – pre-emergence (22nd May), C – post-emergence -5 true leaves (13th June), D – post-emergence (flower bud) (26th June).

Treatment	Application timing	Mean weed cover							
		8th June		26th June		10th July		24th July	
		Ang	Back-trans	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans
UTC*	-	32.5	28.8	77.3	95.2	71.4	89.8	79.9	96.9
Flexidor + Gamit 36 CS	B	**17.9**	**9.4**	**36.8**	**35.8**	**44.8**	**49.7**	**51.3**	**60.8**
Kerb Flo	B	**25.2**	**18.1**	61.6	77.4	68.4	86.5	77.9	95.6
Bonalan	A	**22.6**	**14.8**	62.9	79.3	**54.5**	**66.2**	**60.6**	**75.9**
AHDB 9952	A	**20.4**	**12.2**	**12.9**	**5.0**	**20.9**	**12.7**	**26.5**	**19.9**
AHDB 9995	B	**25.1**	**17.9**	69.0	87.2	71.8	90.3	81.1	97.6
AHDB 9987	B	**16.8**	**8.4**	**53.9**	**65.2**	60.9	76.4	67.5	85.4
AHDB 9987 + Gamit 36 CS	B	**11.3**	**3.8**	**25.7**	**18.7**	**26.2**	**19.5**	**33.1**	**29.7**
AHDB 9918	B	**22.7**	**14.8**	65.8	83.3	64.8	81.8	72.2	90.6
AHDB 9898	B	**17.1**	**8.6**	**55.5**	**67.9**	**57.6**	**71.3**	**64.4**	**81.3**
WING-P	B	**7.9**	**1.9**	**19.5**	**11.2**	**40.4**	**41.9**	**46.4**	**52.5**
AHDB 9998	B	**21.6**	**13.6**	65.1	82.3	65.8	83.3	75.8	94.1
WING-P + AHDB 9998	B	**9.1**	**2.4**	**17.1**	**8.6**	**38.5**	**38.7**	**45.7**	**51.3**
AHDB 9994	B	**21.5**	**13.5**	**39.6**	**40.6**	**43.6**	**47.5**	**49.3**	**57.5**
AHDB 9917	B	**26.3**	**19.7**	71.1	89.5	**53.3**	**64.2**	**59.8**	**74.7**
Flexidor + Gamit 36 CS	C	30.7	26.1	71.2	89.6	72.3	90.7	81.1	97.6
AHDB 9987	C	33.1	29.7	72.3	90.7	68.1	85.9	77.3	95.2
AHDB 9987 + Gamit 36 CS	C	32.3	28.6	60.9	76.4	61.2	76.8	67.8	85.8
AHDB 9994	C	33.2	29.9	**31.1**	**26.6**	**37.4**	**36.9**	**43.8**	**47.8**
Diquat, then AHDB 9985	C D	32.0	28.1	69.8	88.1	74.3	92.7	83.6	98.8
Diquat, then AHDB 9985	C D	34.6	32.3	72.8	91.3	72.9	91.4	84.3	99.0
p value		<.001		<.001		<.001		<.001	
d.f.		20		20		20		20	
L.S.D.		4.028		12.14		10.848		11.36	

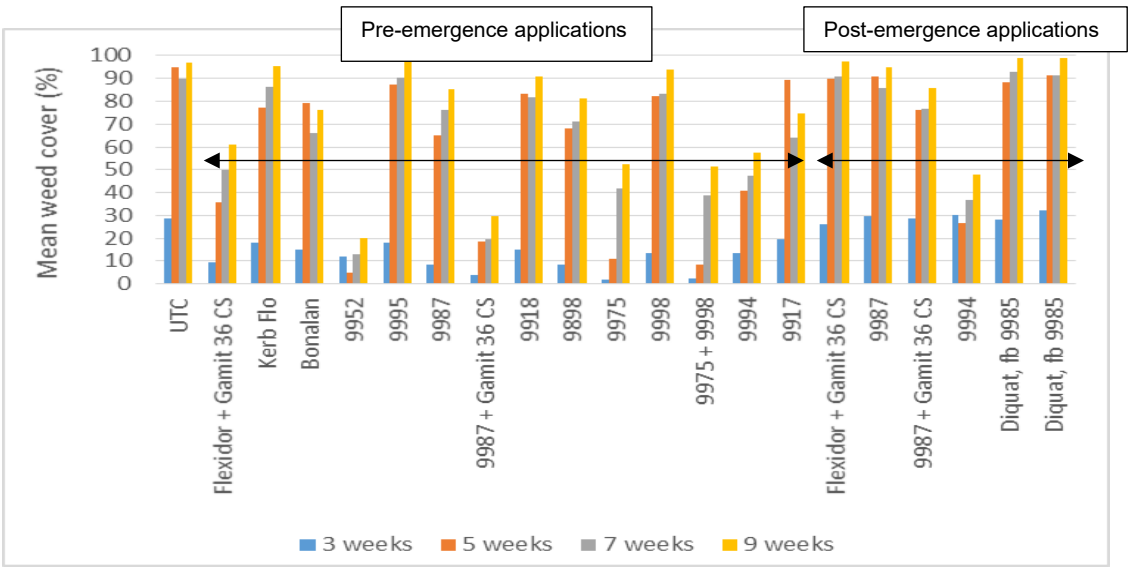


Figure 2. Mean weed cover (%) at baseline assessment and 3, 5, 7 and 9 weeks after treatment application.

Figure 3 illustrates that the total weed cover increased substantially by the final assessment and most treatments experienced a large change in percentage weed cover by 24th July (Table 5). The treatments with the lowest mean weed cover were in plots sprayed pre-emergence with either AHDB 9952 or AHDB 9987 + Gamit 36 CS tank mix. These treatments show a small percentage change in weed cover over the trial period which shows that mean weed cover remained low in these plots throughout the trial period (Table 4).

Table 5. Percentage reduction in weed cover in trial 1 (calculated using Abbotts formula) – highlighted values in red show an increase in weed cover. Application timings: A – pre-emergence and incorporated (21st May), B – pre-emergence (22nd May), C – post-emergence -5 true leaves (13th June), D – post-emergence (flower bud) (26th June).

	Application timing	Weed cover reduction (%)			
		8th June	26th June	10th July	24th July
Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha	B	67.29	62.34	44.63	37.21
Kerb Flo 1.875 L/ha	B	37.32	18.71	3.69	1.34
Bonalan 8.0 L/ha	A	48.65	16.72	26.27	21.62
AHDB 9952	A	57.73	94.75	85.78	79.44
AHDB 9995	B	37.98	8.44	-0.55	-0.70
AHDB 9987	B	70.82	31.47	14.96	11.93
AHDB 9987 + Gamit 36 CS 0.25 L/ha	B	86.69	80.28	78.31	69.30
AHDB 9918	B	48.48	12.51	8.85	6.48
AHDB 9898	B	70.34	28.62	20.58	16.17
WING-P	B	93.31	88.26	53.25	45.81
AHDB 9998	B	52.84	13.49	7.30	2.96
WING-P + AHDB 9998	B	91.41	90.96	56.86	47.12
AHDB 9994	B	53.36	57.32	47.13	40.65
AHDB 9917	B	31.84	5.97	28.55	22.96
Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha	C	9.63	5.82	-1.05	-0.70
AHDB 9987	C	-3.08	4.62	4.25	1.84
AHDB 9987 + Gamit 36 CS 0.25 L/ha	C	0.97	19.70	14.48	11.46
AHDB 9994	C	-3.74	71.99	58.85	50.61
Diquat 2.0 L/ha, then AHDB 9985	C D	2.70	7.41	-3.22	-1.92
Diquat 2.0 L/ha, then AHDB 9985	C D	-11.82	4.12	-1.77	-2.15

Results – Trial 2 (inter-row)

Phytotoxicity

The results of phytotoxicity assessments from four dates are presented in Table 6 and Figure 4. These were scored on a scale from 0 to 10, with 0 being 'dead', and 10 being 'no effect'. Plots deemed to have a commercially acceptable level of damage were scored 8 or above.

Phytotoxicity was recorded using the following scale:

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

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

Shark 0.3 L/ha and Finalsan 34 L/ha + Activator 90 0.2 L/ha applied inter-row with a hooded applicator were crop safe throughout the entire trial period. All treatments were crop safe or very close to safe by the trial conclusion on 24th July (Table 2). There were some transient effects soon after application where Wing-P was applied. In these plots, the crop was stunted and exhibited distorted growth for up to a month after application. The pumpkins grew through this, but did remain a growth stage behind the other plots. The other crop effects were scorch to the edges of leaves where they were caught by the desiccant sprays. Again this was a transient effect, from which the pumpkins recovered from quickly.

Table 6. Mean phytotoxicity scores at four dates throughout the trial period (0 to 10; 0 = complete crop death, 10 = no damage). Scores ≥8 deemed commercially acceptable damage, those <8 (unacceptable damage) are highlighted in red. Application timings: B – pre-emergence (22nd May), C – post-emergence -5 true leaves (13th June), D – post-emergence (flower bud) (26th June).

	Application Timing	Mean crop damage scores			
		12th June	26th June	10th July	24th July
Untreated	-	10.0	10.0	10.0	10.0
Diquat 2.0 L/ha	C	10.0	7.0	7.5	8.5
Shark 0.3 L/ha	C	10.0	8.3	8.5	9.0
AHDB 9897 + Phase II 1.0 L/ha	C	10.0	7.7	8.6	8.5
Finalsan 34.0 L/ha + Activator 90 0.2 L/ha	C	10.0	8.5	8.0	8.7
Finalsan 34.0 L/ha + Activator 90 0.2 L/ha applied twice	C, D	10.0	7.3	7.0	7.7

	Application Timing	Mean crop damage scores			
		12th June	26th June	10th July	24th July
Wing-P 4.0 L/ha	B	4.3	3.7	7.0	8.0
Wing-P 2.0 L/ha	B	5.0	5.7	7.5	8.3
Wing-P 2.0 L/ha + AHDB 9998	B	5.7	6.3	7.8	8.5
p value		<0.001	<0.001	<0.001	<0.001
d.f.		24	24	22	24
L.S.D.		0.5207	1.169	0.893	0.5301

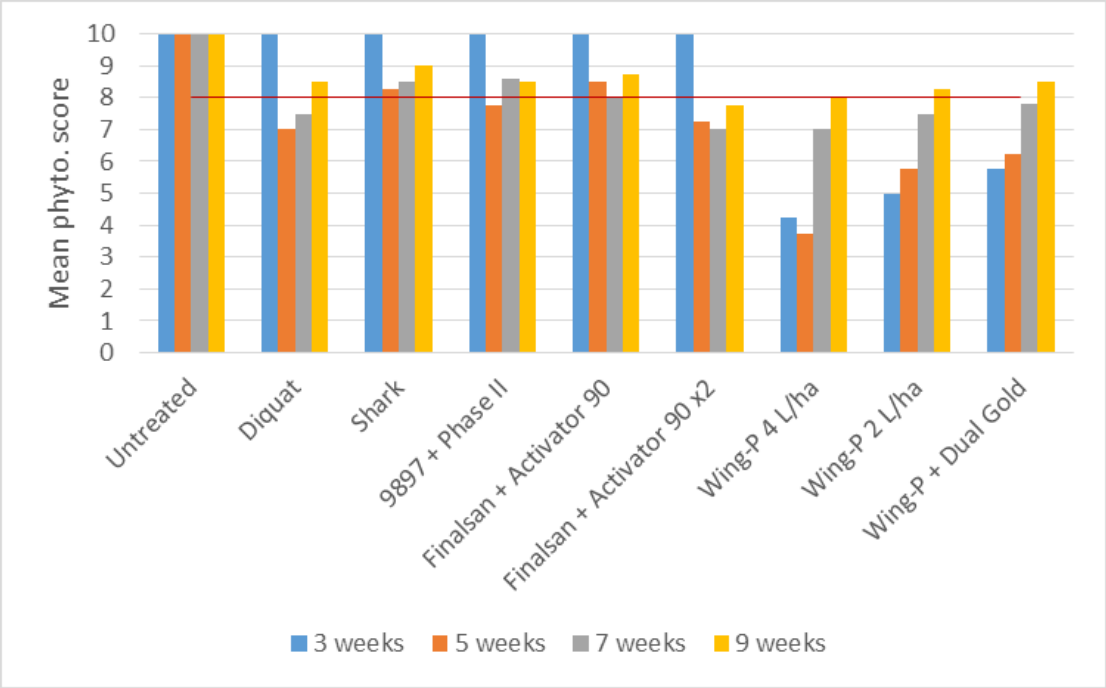


Figure 4. Mean phytotoxicity (0-10) at three, five, seven and nine weeks after treatment application. Scores of 8 or above deemed acceptable damage (as indicated by red line).

Weed control – mean percentage weed cover

The results for the mean percentage weed cover per treatment are presented in Table 7. The percent reduction in weed cover compared to the untreated control was calculated from these figures (using Abbotts formula), and results for each treatment are listed in Table 8.

Table 7. Mean percentage weed cover values at four assessment dates through the trial period (transformed). Values in **bold** are significantly differently from the UTC*. Application timings: pre-emergence (22nd May), post-emergence -5 true leaves (13th June), post-emergence 2 (flower bud) (26th June).

Trt. No.	Mean weed cover															
	12th June				26th June				10th July				25th July			
	In Row		Outside Row		In Row		Outside Row		In Row		Outside Row		In Row		Outside Row	
	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans
Untreated	36.27	35.0	37.7	37.48	71.4	89.86	70.9	89.3	72.9	91.4	72.9	91.4	79.8	96.83	82.5	98.28
Diquat 2.0 L/ha	-	-	-	-	71.4	89.86	**46.3**	**52.24**	64.1	80.85	**47.3**	**53.93**	72.1	90.5	**53.7**	**65.01**
Shark 0.3 L/ha	-	-	-	-	69.8	88.1	**8.5**	**2.18**	66.9	84.65	**12.4**	**4.59**	72.1	90.56	**13.2**	**5.25**
AHDB 9897 + Phase II 1.0 L/ha	-	-	-	-	64.4	81.36	**7.9**	**1.89**	64.4	81.3	**9.3**	**2.63**	70.5	88.83	**10.6**	**3.36**
Finalsan 34.0 L/ha + Activator 90 0.2 L/ha	-	-	-	-	68.6	86.68	**56.9**	**70.12**	62	77.99	**51.9**	**61.94**	70.6	88.95	**58.3**	**72.36**
Finalsan 34.0 L/ha + Activator 90 0.2 L/ha applied twice	-	-	-	-	69	87.12	**38.9**	**39.41**	**59.2**	**73.78**	**44.2**	**48.6**	**65.7**	**83.08**	**49.6**	**58.01**
Wing-P 4.0 L/ha	**23.9**	**16.47**	**6.4**	**1.22**	65.3	82.51	**14.2**	**6.01**	**59.8**	**74.67**	**16.8**	**8.32**	68.6	86.74	**18.9**	**10.45**
Wing-P 2.0 L/ha	**24.9**	**17.73**	**7.9**	**1.93**	64.1	80.85	**13.5**	**5.48**	69.2	87.45	**21.1**	**12.98**	78.5	96.00	**25.5**	**18.58**
Wing-P 2.0 L/ha + AHDB 9998	**29.0**	**23.50**	**9.2**	**2.55**	65.6	82.87	**17.7**	**9.25**	65.7	83.08	**19.2**	**10.85**	72.9	91.31	**20.1**	**11.76**
p value	<.001		<.001		0.823		<.001		0.442		<.001		0.49		<.001	
d.f.	24		24		24		24		24		24		24		24	
L.S.D.	4.74		4.951		11.82		15.10		12.72		12.85		13.2		14.22	

All treatments significantly reduced percentage weed cover in the outside row – the inter-row treated area - at all dates throughout the duration of the trial assessment period (Table 7 and 8). In addition, Finalsan + Activator 90 applied twice and Wing-P at 4 L/ha applied pre-emergence, significantly reduced weed levels within the crop row by up to 19.3%. Wing-P is likely to have moved into the crop row to cause the extra weed reduction outside the area where the product was applied. The increased efficacy of the Finalsan treatment is unexpected.

The best performing treatment was AHDB 9897 + Phase II with the lowest weed cover in the outside row, at only 10.6% mean weed cover by the trial conclusion, therefore was the most effective in terms of weed cover reduction. This is followed closely by 'Shark', which also showed consistently low weed cover relative to the other treatments.

Table 8. Percentage reduction in weed cover at four dates in the trial period (calculated using Abbotts formula) – red values show an increase in weed cover.

	Weed cover reduction (%)							
	12th June		26th June		10th July		25th July	
	Within Row	Outside row	Within Row	Outside row	Within Row	Outside row	Within Row	Outside row
Diquat 2.0 L/ha	-	-	0.00	41.50	11.54	41.00	6.54	33.85
Shark 0.3 L/ha	-	-	1.96	97.56	7.39	94.98	6.48	94.66
AHDB 9897 + Phase II 1.0 L/ha	-	-	9.46	97.88	11.05	97.12	8.26	96.58
Finalsan 34.0 L/ha + Activator 90 0.2 L/ha	-	-	3.54	21.48	14.67	32.23	8.14	26.37
Finalsan 34.0 L/ha + Activator 90 0.2 L/ha applied twice	-	-	3.05	55.87	19.28	46.83	14.20	40.97
Wing-P 4.0 L/ha	52.94	96.74	8.18	93.27	18.30	90.90	10.42	89.37
Wing-P 2.0 L/ha	49.34	94.85	10.03	93.86	4.32	85.80	0.86	81.09
Wing-P 2.0 L/ha + AHDB 9998	32.86	93.20	7.78	89.64	9.10	88.13	5.70	88.03

AHDB 9897 + Phase II shows consistently reduced weed levels from the assessment on 26th June onwards and caused the greatest per-cent weed cover reduction at the trial end with a mean 97% reduction compared to the untreated (results of Abbott's reduction formula, Table 8). This is closely followed by 'Shark', which caused a mean 95% reduction in weed cover compared to the untreated by the trial end.

Discussion

The weeds present were mainly fat-hen, chickweed, redshank and small nettle. Smaller populations of mayweed, field pansy, black nightshade and barnyard grass were also present.

Trial 1

Treatments which were both crop safe, or close to crop safe and significantly reduced weed levels compared to the untreated were pre-emergence treatments; Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha, Bonalan 8 L/ha, AHDB 9898, AHDB 9994, AHDB 9917, and AHDB 9987 + Gamit 36 CS 0.25 L/ha. These were all applied pre-emergence. Only Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha was crop safe post-emergence, but AHDB 9987 + Gamit 35 CS 0.25 L/ha was near to crop safe and no plant losses were observed and therefore would be worth revisiting as it has been safe applied over cucurbits in previous trials in SCEPTRE, and there are very few herbicides which are safe to use post-emergence in pumpkins. AHDB 9898 was the only

treatment to significantly reduce total mean weed cover at every assessment as well as having crop safe phytotoxicity scores at every assessment.

There were several treatments which scored just under a commercially acceptable level mainly due to slight stunting, but pumpkins still developed and the following would be worth considering further, as they offer useful weed control of either general weeds, or selected problem weeds such as grasses. These treatments were Bonalan 8.0 L/ha, AHDB 9917 and AHDB 9994 applied pre-emergence, as well as AHDB 9985 and AHDB 9987 applied either alone or with Gamit 36 CS post-emergence. AHDB 9985 caused transient yellowing. AHDB 9985 is a graminicide and would improve control of grasses. This product did not significantly reduce weed numbers in this trial as were mainly broad-leaved weeds present. However, authorisation would still be useful for growers in situations where grass weeds are present.

AHDB 9952, and Wing-P at either 2.0 or 4.0 L/ha applied pre-emergence caused severe stunting and distortion, while AHDB 9994 applied post-emergence severely scorched the plants and therefore these products are not safe to use in pumpkins at these timings.

Trial 2
Shark 0.3 L/ha and Finalsan 34 L/ha + Activator 90 0.2 L/ha applied inter-row with a hooded applicator were crop safe throughout the entire trial period. All treatments were crop safe or very close to safe by the trial conclusion on 24th July (Table 2). There were some transient effects soon after application where Wing-P was applied. In these plots, the crop was stunted and exhibited distorted growth for up to a month after application. The pumpkins grew through this but did remain a growth stage behind the other plots. The other crop effects were scorch to the edges of leaves where they were caught by the desiccant sprays. Again this was a transient effect, from which the pumpkins recovered from quickly.

All treatments significantly reduced percentage weed cover in the outside row – the inter-row treated area - at all dates throughout the duration of the trial assessment period (Table 7 and 8). In addition, Finalsan + Activator 90 applied twice, and Wing-P 4 L/ha applied pre-emergence, significantly reduced weed levels within the crop row by up to 19.3%. Wing-P is likely to have moved into the crop row to cause the extra weed reduction outside the area where the product was applied. The increased efficacy of the Finalsan treatment is unexpected.

The best performing treatment was AHDB 9897 + Phase II with the lowest weed cover in the outside row, at only 10.6% mean weed cover by the trial conclusion, therefore was the most effective in terms of weed cover reduction. This is followed closely by ‘Shark’, which also showed consistently low weed cover relative to the other treatments. Finalsan 34 L/ha + Activator 90 0.2 L/ha performed equivalent to the commercial standard in 2018 of diquat 2.0 L/ha.

Conclusions

Trial 1

- Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha and AHDB9898 applied pre-emergence. were both crop safe throughout the trial and significantly reduced weed cover compared to the untreated control at the final assessment.
- Bonalan 8.0 L/ha, AHDB 9994, AHDB 9917 and AHDB 9987 + Gamit 36 CS 0.25 L/ha significantly reduced weed levels and were near to crop safe causing on slight stunting or yellowing which was transient.
- AHDB 9987 + Gamit 36 CS 0.25 L/ha could be useful at both pre- and post-emergence application timings.

Trial 2

- All treatments significantly reduced percentage weed cover in the inter-row treated area.
- All treatments were crop safe except for Finalsan 34.0 L/ha + Activator 90 applied twice, but even this treatment effect was just below the acceptable limit.

- Wing-P caused stunting which persisted until the end of the trial but was deemed acceptable.

Acknowledgements

AHDB for funding the work, and the crop protection companies for their financial contributions as well as providing samples for the trials. Thanks should also be given to the growers who provided sites and crops for the trials as well as technical input, particularly Neil Cairns and Sergej Lonskis of Barfoots.

Appendix

a. Crop diary – events related to growing crop

Site 1:

Crop	Cultivar	Drilling date	Row width (m)
Pumpkin	Racer	22/05/2018	0.83

Previous cropping

Year	Crop
2017	Winter wheat
2016	Sweetcorn
2015	Pumpkins

Cultivations

Date	Description	Depth (cm)
11/05/2018	Ploughing	25
18/05/2018	Power harrowing	15

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

Date	Product	Rate
22/04/2018	Digestate	50m^3
21/07/2018	30.0.0.19	300 kg/ha

Pesticides applied to trial area

Date	Product	Rate (L/ha)
17/04/2018	Azural	3.0

Details of irrigation regime

Date	Type, rate and duration	Amount applied (mm)
18/06/2018	Overhead gun	15
22/06/2018	Overhead gun	10

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

Date	Event
21/05/2018	Timing A treatments sprayed and incorporated (trial 1).

	Trial drilled.
22/05/2018	Timing B treatments applied.
08/06/2018	Assessment – phytotoxicity, weed cover (trial 1 only).
12/06/2018	Assessment – phytotoxicity, weed cover (trial 2 only).
13/06/2018	Timing C treatments applied.
26/06/2018	Timing D treatments applied. Assessment – phytotoxicity, weed cover.
10/07/2018	Assessment – phytotoxicity, weed cover, crop vigour.
24/07/2018	Assessment – phytotoxicity, weed cover.

c. Photos of phytotoxic crop effects on 26th June – 1 month after pre-emergence application (B), and 2 weeks after 1st inter-row application (C)

		
Untreated control	Wing-P 2 L/ha pre-emergence crop loss and severe stunting	Wing-P crop effect detail

		
AHDB 9952 – severe stunting	AHDB 9994 pre-emergence slight stunting	AHDB 9994 post emergence stunting and scorch

	
Flexidor + Gamit pre-emergence (standard)	Wing-P inter-row and phytotoxicity effects where it has leached into the row

d. Climatological data during study period from each site.

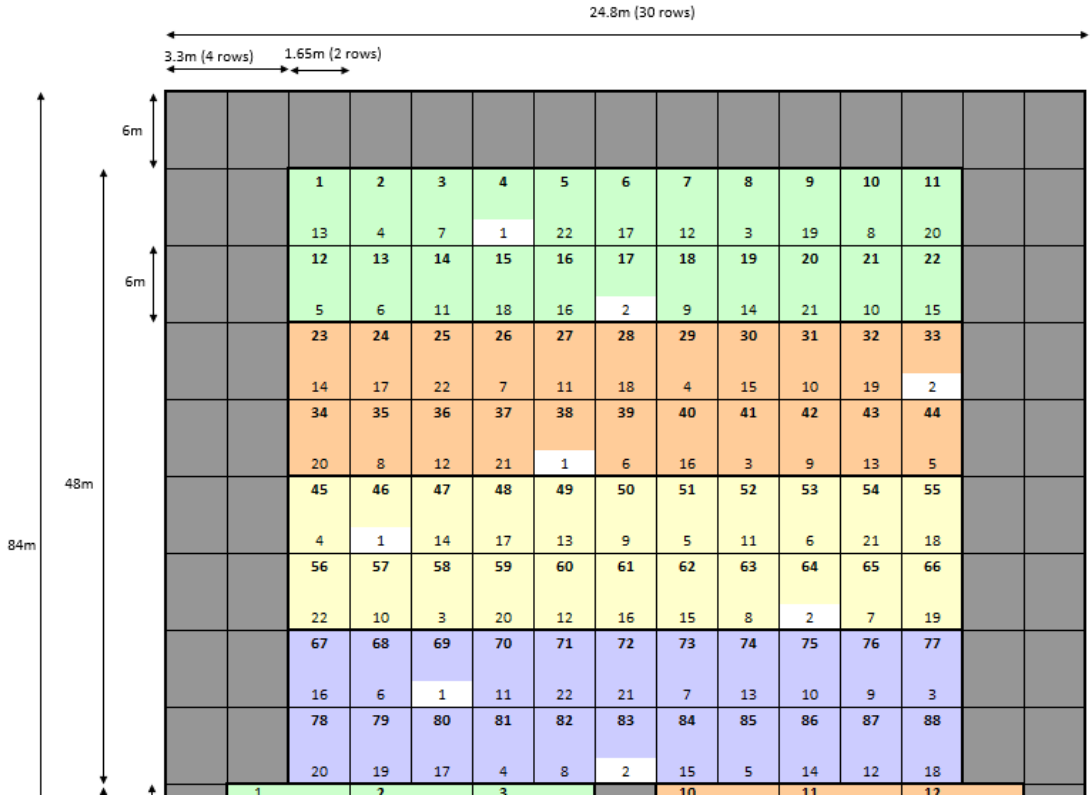
Date	Temperature °C (minimum)	Temperature °C (maximum)	Rainfall* (mm)
21/05/2018	15.0	24.0	2.4
22/05/2018	14.5	26.5	0.0
23/05/2018	9.5	23.5	0.0
24/05/2018	11.5	17.5	4.8
25/05/2018	12.0	21.0	0.0
26/05/2018	14.0	28.5	3.0
27/05/2018	16.0	24.5	4.2
28/05/2018	14.5	26.5	0.0
29/05/2018	15.0	20.0	7.2
30/05/2018	14.0	18.0	16.0
31/05/2018	14.5	20.5	3.4
01/06/2018	13.0	17.5	0.2
02/06/2018	13.5	20.0	0.0
03/06/2018	11.0	25.0	0.0
04/06/2018	15.0	21.5	0.0
05/06/2018	13.5	19.0	0.0
06/06/2018	9.5	24.5	0.0
07/06/2018	13.5	19.0	2.0
08/06/2018	14.0	23.5	0.0
09/06/2018	12.0	21.5	0.0
10/06/2018	15.0	24.5	0.0
11/06/2018	14.0	26.0	0.0
12/06/2018	13.0	22.5	0.0
13/06/2018	9.5	21.5	0.0
14/06/2018	14.0	23.5	0.2
15/06/2018	9.5	21.5	0.2
16/06/2018	13.0	18.5	0.0
17/06/2018	13.0	18.5	0.4
18/06/2018	14.5	21.5	0.0
19/06/2018	15.0	21.5	0.0
20/06/2018	14.5	20.5	0.0
21/06/2018	11.0	21.0	0.4
22/06/2018	8.0	22.5	0.2
23/06/2018	9.5	25.0	0.0
24/06/2018	11.0	26.5	0.0
25/06/2018	10.5	28.0	0.0
26/06/2018	11.0	27.5	0.0
27/06/2018	8.5	31.0	0.0
28/06/2018	12.0	31.0	0.0
29/06/2018	14.0	32.0	0.0
30/06/2018	12.5	35.0	0.0
01/07/2018	16.0	38.0	0.0
02/07/2018	19.0	37.0	0.0
03/07/2018	15.5	33.5	0.0
04/07/2018	15.0	28.5	0.0
05/07/2018	14.5	31.0	0.0
06/07/2018	13.0	38.0	0.0
07/07/2018	14.5	35.0	0.0
08/07/2018	16.0	37.5	0.0
09/07/2018	13.5	34.5	0.0
10/07/2018	14.5	32.5	0.0
11/07/2018	11.5	32.0	0.0
12/07/2018	11.0	30.5	0.0

* Data collected from Gosport Weather Station.

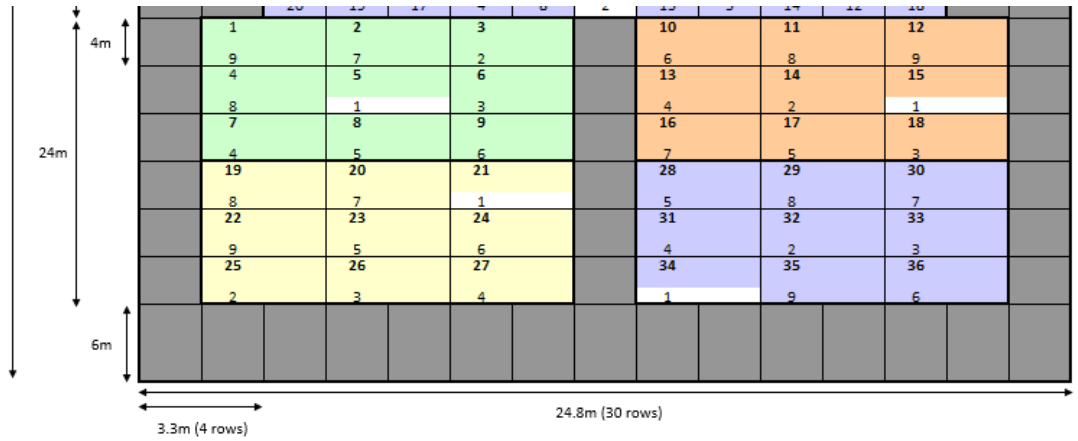
Date	Temperature °C (minimum)	Temperature °C (maximum)	Rainfall* (mm)
13/07/2018	14.5	31.5	0.0
14/07/2018	12.5	33.0	0.0
15/07/2018	10.5	35.0	0.0
16/07/2018	12.0	34.0	0.0
17/07/2018	12.0	25.5	0.0
18/07/2018	11.0	27.5	0.0
19/07/2018	11.0	32.0	0.0
20/07/2018	17.5	30.5	0.0
21/07/2018	17.0	32.0	1.8
22/07/2018	13.5	32.5	0.0
23/07/2018	14.5	33.0	0.0
24/07/2018	15.0	33.0	0.0
25/07/2018	18.0	33.0	0.0
26/07/2018	23.0	25.0	0.0
27/07/2018	23.5	25.5	1.2
28/07/2018	22.0	24.5	1.2
29/07/2018	21.0	22.0	15.2
30/07/2018	20.0	21.0	0.2

e. Trial design

TRIAL1



TRIAL 2



f. ORETO certificate

Certificate of

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

This certifies that

RSK ADAS Ltd

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

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

Agriculture/Horticulture
Stored Crops
Biologicals and Semiochemicals

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

Signature Alison Richardson
Authorised signatory

Certification Number
ORETO 409

HSE
Chemicals Regulation Division

Department of Agriculture and Rural Development