SCEPTREPLUS

Final Trial Report

Trial code:	SP13
Title:	Improving weed control in cucurbits (courgettes)
Crop	Field vegetables – Cucurbita (courgette)
Target	General broadleaf weeds and grasses
Lead researcher:	Angela Huckle
Organisation:	RSK ADAS
Period:	May 2017 – December 2017
Report date:	2 January 2018
Report author:	Angela Huckle Emily Lawrence
ORETO Number: (certificate should be attached)	376

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

2 January 2017

A Huckle

…… ……

Date Authors signature

Grower 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; isoxaben, propyzamide and, most recently, clomazone which gained approval in 2015 to improve control of groundsel. Diquat is also approved for inter-row application to control emerged weeds after planting, but it only offers temporary suppression and often needs to be repeated.

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 a number of 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. For some growers, it is therefore common practice to apply authorised herbicides via hooded tractor-mounted spray applicators to shield the crop foliage. 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. Further options are therefore required inter-row as well as over the row.

Methodology

A trial was sited at a commercial courgette grower in West Sussex. Treatments were applied in combinations either pre-planting or post-planting, or in sequence pre and post-planting. There were two separate pre-planting application methods; incorporated and non-incorporated. All nine treatments were applied to the soil surface, with the treatments benfluralin (Bonalan) and AHDB9952 only then incorporated to a depth of 20cm with a small rotovator. The courgette seedlings (var. Kronos) were planted the day after the pre-planting applications on 4 July 2017 at two true leaves, and the post-planting treatments were applied on 5 July within 24 hours of planting. No plastic mulch was used. The inter-row application of carfentrazone-ethyl (Shark) was applied at a growth stage of first flower, approximately four weeks after planting. The treatments were applied with either a 2m boom or a single nozzle hooded lance as required and an Oxford precision knapsack sprayer at 200 L/ha water volume with plots 2m wide by 8m long. To simulate weed control that would normally have been achieved from plastic mulch on the beds in the inter-row treatments, hoeing was carried out on the beds at around four weeks after planting.

A randomised block design was used with four replicates of seventeen treatments plus two untreated controls and two post emergence grower standards for comparison giving 84 plots in total. Plots were assessed for weed control on five occasions, using counts of weed species at the first assessment while the weeds were at seedling stage, and then % weed ground cover was used once the weeds were larger for the latter four assessments. Crop damage was also recorded at one week after planting, and at the same time that weed control was assessed giving five phytotoxicity assessments. Harvest assessments for gross and marketable yield were made by Barfoot's staff from five representative plants in the central six metres of the plots – fruit with >16cm lengths were picked, categorised by diameter, and weighed.

Results and discussion

All treatments except AHDB9995 significantly reduced the mean percentage weed cover ($p < 0.001$). Of the experimental treatments the greatest weed control (>90% reduction on 22 August pre-harvest) was achieved by five treatments; AHDB9987 tank-mixed with Flexidor or Flexidor + Gamit 36 CS; Stomp Aqua + Gamit 36 CS + AHDB9947 in a tank-mix pre-planting, Bonalan pre-planting followed by Flexidor + Gamit 36 CS, and Wing-P pre-planting followed by AHDB9987. However, these and many other treatments were not crop safe to the courgettes despite giving effective weed control (Table 1).

Six treatments combined acceptable crop safety, or close to acceptable crop safety with reasonably effective weed control; the standard Flexidor + Gamit 36 CS, Bonalan or Wing-P applied at a reduced rate pre-planting followed by Gamit 36 CS post-planting, Wing-P or Stomp Aqua applied at reduced rates inter-row with Gamit 36 CS post-planting, and AHDB9987 in a tank-mix with Gamit 36 CS applied post-planting.

All treatments with the exception of the lower rate of AHDB9995 gave higher yields than the untreated control, in those that were assessed. Three treatments gave significantly greater yields than the untreated control, these were the commercial standard, Flexidor + Gamit 36 CS, and the two inter-row treatments; Stomp Aqua + Gamit 36 CS and Wing-P + Gamit 36 CS.

Despite giving poor weed control in this trial AHDB9995 should not be overlooked for further work as it gives useful control of annual meadow grass, black-bindweed, black-grass, knotgrass, pale persicaria and wild oat which have been reported as problematic by growers. The weed species present in this trial would not have been well controlled by AHDB9995, as the main species were fat-hen and barnyard grass which are only moderately susceptible to this herbicide. Therefore further work is required with AHDB9995 to find suitable tank-mix partners to cover a wider weed spectrum.

The standard treatments performed as expected and were comparable to commercial practice. There were no issues with mixing or application of any products. No wetters were used.

Table 1. Summary of crop damage, percentage weed cover and gross yield from key assessment timings

Timing A and B 3rd July (Pre-planting)	**Timing C 5th July (Post-planting)**	**Timing D 1st Aug (4 weeks post planting)**	**crop damage (0-10) 22nd August (pre-harvest)**	**weed cover* (%) 8th September (mid-harvest)**	**gross yield (t/ha) multiple dates (30 Aug – 2 Oct)**
Untreated	-	-	9.00	93.31	17.37
-	Kerb 1.0 L/ha + Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha (Standard 1)	-	**7.75**	**30.85**	(not assessed)
-	Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha (Standard 2)	-	**7.75**	**50.07**	**29.48**
Bonalan 8.0 L/ha	Gamit 36 CS 0.25 L/ha	-	**7.75**	**59.29**	20.79
Bonalan 8.0 L/ha	Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha	-	**5.25**	**12.51**	(not assessed)
AHDB9952	-	-	**5.75**	**23.68**	(not assessed)
AHDB9995 high	-	-	9.00	89.30	20.62
AHDB9995 low	-	-	8.91	91.26	8.05

Timing A and B 3rd July (Pre-planting)	Timing C 5th July (Post-planting)	Timing D 1st Aug (4 weeks post planting)	crop damage (0-10) 22nd August (pre-harvest)	weed cover* (%) 8th September (mid-harvest)	gross yield (t/ha) multiple dates (30 Aug – 2 Oct)
Wing-P 2.0 L/ha	Gamit 36 CS 0.25 L/ha	-	**7.38**	**29.37**	23.16
-	Wing-P 2.0 L/ha + Gamit 36 CS 0.25 L/ha inter-row	-	8.75	**20.82#**	**27.77**
Stomp Aqua 2.3 L/ha	Gamit 36 CS 0.25 L/ha	-	**6.63**	**56.71**	(not assessed)
-	Stomp Aqua 2.3 L/ha + Gamit 36 CS 0.25 L/ha inter-row	-	9.00	**17.88#**	**29.93**
Stomp Aqua 2.3 L/ha+ Gamit 36 CS 0.25 L/ha + AHDB9947	-	-	**5.30**	**31.27**	(not assessed)
Wing-P 2.0 L/ha	AHDB9987	-	**6.50**	**40.86**	(not assessed)
-	AHDB9987 + Gamit 36 CS 0.25 L/ha	-	8.12	**22.73**	23.14
-	AHDB9987 + Flexidor 0.5 L/ha	-	**4.75**	**8.03**	(not assessed)
-	AHDB9987 + Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha	-	**6.00**	**13.00**	(not assessed)
-	AHDB9985 + Flexidor 0.5 L/ha	-	**6.50**	**67.99**	(not assessed)
-	AHDB9985 + Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha	-	**6.50**	**24.00**	(not assessed)
-	Flexidor 0.5 L/ha + Gamit 36 CS 0.25 L/ha	Shark 0.3 L/ha	**6.75**	**20.23**	(not assessed)
		F-prob	**<0.001**	**<0.001**	**<0.001**
		d.f.	**57**	**57**	**22**
		S.E.D.	**0.772**	**5.62**	**3.882**
		L.S.D.	**1.546**	**11.25**	**8.051**

Yield assessments were carried out on the most promising plots in terms of crop selectivity.
* % weed cover was assessed as a whole plot score for all treatments with the exception of those which were inter-row applications. In the inter-row treatment, only the inter-row parts of the plot were assessed as hoeing was used to simulate mulch and control weed. These treatment results are marked with a #
Crop Damage – Red = unacceptable, Yellow = marginal, Green = safe
Weed control – Red = > 50% weed cover, Yellow = 25-50% weed cover, Green = <25% weed cover
Bold = significantly different to the untreated

Conclusions and Take Home Message

- Wing-P or Stomp Aqua applied inter-row in a tank-mix with Gamit 36 CS gave improved weed control compared to the current standard, was crop safe, and gave equivalent yields to the current standard.
- An application for an EAMU for Wing-P for inter-row use in courgettes has been submitted.
- AHDB9987 applied in a tank mix with Gamit 36 CS post-planting shows promise in controlling weeds in courgettes with no phytotoxic effects in this trial.
- AHDB9995 and Bonalan pre-planting followed by Gamit 36 CS were safe to the courgettes, but gave poor weed control of the weed species on site. Tank-mixing or being included in sequence with other products could improve the range of weed species controlled. Further work is needed to investigate possible safe product combinations.
- Further studies should also be repeated on the newer products Bonalan and AHDB9987.

Objectives

1. To evaluate the effectiveness of 19 herbicide treatments applied in combinations either pre-planting or post-planting, or in sequence pre and post emergence against broadleaved weeds and grasses in courgettes as measured by crop safety, weed control efficacy and gross yield
2. To compare performance against the commercial standard (clomazone, propyzamide and isoxaben or isoxaben + clomazone post-planting)
3. To monitor the treated crop for phytotoxicity

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 1/152(3)	Design and analysis of efficacy evaluation trials	None
PP 1/135(3)	Phytotoxicity assessment	None
PP 1/181(3)	Conduct and reporting of efficacy evaluation trials including GEP	None
PP 1/214 (3)	Principles of acceptable efficacy	None
PP 1/224 (2)	Principles of efficacy evaluation for minor uses	None
PP 1/118(3)	Weeds in outdoor fruit vegetables	None

Deviations from EPPO guidance: None

Test site

Item	**Details**
Location address	Field: Big Field Barfoots (Easton Farm) Almodington Hants Grid reference: SZ 83797 97974
Crop	Courgette
Cultivar	Kronos
Soil or substrate type	Silty clay loam
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:	60cm (2 rows per plot)
Plot size: (w x l)	2m x 8m
Plot size: (m^2)	$16m^2$
Number of plants per plot:	Approx 18
Leaf Wall Area calculations	N/A

Treatment details

AHDB Code	Active substance	Product name or manufacturers code	Formulation batch number	Content of active substance in product (g/L)	Formulation type
N/A (standard)	propyzamide	Kerb Flo	F470FBM013	400	Suspension Concentrate
N/A (standard)	isoxaben	Flexidor 500	F0026G23C01	500	Suspension Concentrate
N/A (standard)	clomazone	Gamit 36 CS	160344	360	Capsule Suspension
N/A	benfluralin	Bonalan	GLGAL7112	150	Emulsifiable concentrate
AHDB9952	N/D	N/D	N/D	N/D	N/D
AHDB9995	N/D	N/D	N/D	N/D	N/D
N/A	dimethenamid-p + pendimethalin	Wing-P	0014243535	212.5 + 250	Emulsifiable Concentrate
N/A	pendimethilin	Stomp Aqua	OO13054353	455	Capsule suspension
AHDB9947	N/D	N/D	N/D	N/D	N/D
AHDB9987	N/D	N/D	N/D	N/D	N/D
AHDB9985	N/D	N/D	N/D	N/D	N/D
N/A	carfentrazone-ethyl	Shark	N/K	60	Micro Emulsion

Application schedule

Treatment number	Treatment: product name or AHDB code	Rate of active substance (ml or g a.s./ha)	Rate of product (l/ha)	Application code
1	Untreated	-	-	-
2	Untreated	-	-	-
3	Kerb + Flexidor + Gamit 36 CS	400 250 90	1.0 0.5 0.25	C
4	Flexidor + Gamit 36 CS	250 90	0.5 0.25	C
5	Bonalan*	1200	8.0	A
	Gamit 36 CS	90	0.25	C
6	Bonalan*	1200	8.0	A
	Flexidor + Gamit 36 CS	250 90	0.5 0.25	C
7	AHDB9952*	1800	4.0	A
8	AHDB9995	800	2.0	B
9	AHDB9995	400	1.0	B
10	Wing-P	925	2.0	B
	Gamit 36 CS	90	0.25	C
11	Wing-P + Gamit 36 CS**	925 90	2.0 0.25	C
12	Stomp Aqua	1046.5	2.3	B
	Gamit 36 CS	90	0.25	C
13	Stomp Aqua + Gamit 36 CS**	1046.5 90	2.3 0.25	C

Treatment number	Treatment: product name or AHDB code	Rate of active substance (ml or g a.s./ha)	Rate of product (l/ha)	Application code
14	Stomp Aqua + Gamit 36 SC + AHDB9947	1046.5 90 480	2.3 0.25 1.2	B
15	Wing-P	925	2.0	B
	AHDB9987	1200	2.0	C
16	AHDB9987 + Gamit 36 CS	1200 90	2.0 0.25	C
17	AHDB9987 + Flexidor	1200 250	2.0 0.5	C
18	AHDB9987 + Flexidor + Gamit 36 CS	1200 250 90	2.0 0.5 0.25	C
19	AHDB9985 + Flexidor	120 250	1.0 0.5	C
20	AHDB9985 + Flexidor + Gamit 36 CS	120 250 90	1.0 0.5 0.25	C
21	Flexidor + Gamit 36 CS	250 90	0.5 0.25	C
	Shark**	19.8	0.33	D

* incorporated
** inter-row

Application details

	Application A	Application B	Application C	Application D
Application date	03/07/2017	03/07/2017	05/07/2017	01/08/2017
Time of day	12:45 – 13:30	13:30 – 14:30	09:45 – 11:50	16:30 – 17:00
Crop growth stage (Max, min average BBCH)	N/A	N/A	13	61
Crop height (cm)	N/A	N/A	12	15
Crop coverage (%)	N/A	N/A	20	40
Application Method	spray & incorporation	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	2.4 bar	2.4 bar	2.4 bar
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)	21.2	21.2	21.1	18.6
Relative humidity (%)	73.9	73.9	62.3	82.7
Wind speed range (mph)	10.7 -11.5 (guard board used between plots)	10.7 -11.5 (guard board used between plots)	3.7 – 4.7	11.5 – 12.0 (hooded applicator used)
Dew presence (Y/N)	N	N	N	N
Temperature of soil - 10cm (°C)	22.0	22.0	20.0	22.0
Wetness of soil - 2-5 cm	Damp	Damp	Damp	Damp
Cloud cover (%)	50	50	5	50

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

Common name	**Scientific Name**	**EPPO Code**	**Infection level pre-application**	**Infection level at start of assessment period** (2 weeks)	**Infection level mid-assessment period** (4 weeks)	**Infection level at end of assessment period** (9 weeks)
Broad leaved weeds and grasses	*N/A*	3WEEDT	0%	2.31% *(untreated average)*	32.26% *(untreated average)*	93.31% *(untreated average)*

Assessment details

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)
13/07/2017	9	15	phytotox	Phytotox (scale 0-10, 0 = Dead)
19/07/2017	15	19	efficacy, phytotox	Phytotox (scale 0-10, 0 = Dead) Counts of weed species per quadrat, 3 x 25cm x 25cm quadrats per plot)
02/08/2017	29	61	efficacy, phytotox	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover, whole plot score
15/08/2017	42	71	efficacy, phytotox	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover, whole plot score
22/08/2017	49	72	efficacy, phytotox	Phytotox (scale 0-10, 0 = Dead) Percentage of weed cover, whole plot score; weed species presence
08/09/2017	66	89	efficacy	Percentage of weed cover, whole plot score; weed species presence
30/08/2017 To 03/10/2017	57 to 91	89	yield	Gross yield, yield per plant, yield per hectare

* DA – days after application C

Statistical analysis

The trial design was a randomised block design, with four replicates of 21 treatments, including two untreated controls and a grower standard.

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

All data were analysed by ANOVA using the Genstat 18.4 by Chris Dyer at RSK ADAS. For the % efficacy data calculated by Abbots formula, an angular transformation was carried out and then the back transformed means are presented from which Abbotts Formula was used to calculate the % reduction in weeds.

Results

Phytotoxicity

The results of phytotoxicity assessments from five dates are presented in Table 1 and from four dates in Figure 1. These were scored on a scale of 1 to 10, with 1 being dead, and 10 being no effect. Those scores at 8 or above were deemed to be commercially acceptable damage.

Phytotoxicity was be 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.

Eleven of the treatments caused unacceptable damage to the courgette crop which was exhibited as a severe stunting and check to crop growth which continued up to the point of the start of harvest. The courgette plants affected continued to remain smaller than the plants in the untreated plots throughout, and did not recover to an acceptable level by the start of harvest. Example photos in Appendix D. Eight of those treatments also caused death of some plants in the plots. These were; AHDB9952 applied pre-planting, any treatments where Stomp Aqua was included pre-planting, Wing-P pre-planting followed by AHDB9987 post-planting, AHDB9987 applied post-planting when Flexidor was included in the tank mix, and tank-mixes which included AHDB9985 applied post-planting. However, AHDB9985 appeared safe when applied alone at flowering stage post-planting in an un-replicated observation plot. This treatment was not included in the randomised trial and would warrant further testing.

The standards Flexidor + Gamit 36 CS and Kerb Flo + Flexidor + Gamit 36 CS applied over the crop caused a check to the crop, but the courgette plants grew through this check and there was no crop loss. Growers are aware that this can happen as courgettes are very sensitive, so therefore these herbicides are usually applied as an inter-row application, or at a later time after transplanting, especially where Kerb Flo is included. In this trial treatments were applied within 24 hours after transplanting to test the most sensitive situation.

Seven treatments were safe or very close to safe by harvest and warrant further work to confirm or improve crop safety by adjusting the rates. These are Bonalan at 8.0 L/ha applied pre-planting followed by Gamit 36 CS at 0.25 L/ha post-planting, AHDB9995 applied pre-planting, Wing-P at 2.0 L/ha followed by Gamit 36 CS at 0.25 L/ha post-planting, Wing-P at 2.0 L/ha or Stomp Aqua at 2.3 L/ha applied inter-row followed by Gamit 36 CS applied over the row at 0.25 L/ha, and AHDB9987 + Gamit 36 CS at 0.25 L/ha applied post-planting.

Table 1 Mean phytotoxicity scores through the trial. (Scores 8 or above deemed acceptable damage). Those below 8 and thus unacceptable are marked in **bold**.

Timing A and B	Timing C	Timing D	Mean crop damage scores				
			13th Jul	19th Jul	2nd Aug	15th Aug	22nd Aug
Untreated	-	-	9.00	9.00	9.00	9.00	9.00

-	Kerb + Flexidor + Gamit 36 CS	-	**6.75**	**6.50**	**6.25**	**7.25**	**7.75**
-	Flexidor + Gamit 36 CS	-	**7.50**	**7.00**	**7.75**	**7.75**	**7.75**
Bonalan	Gamit 36 CS	-	**6.50**	**7.00**	**7.00**	**7.25**	**7.75**
Bonalan	Flexidor + Gamit 36 CS	-	**6.41**	**4.25**	**4.25**	**5.00**	**5.25**
AHDB9952	-	-	**6.75**	**5.25**	**4.50**	**5.75**	**5.75**
AHDB9995 high	-	-	8.50	8.50	8.50	9.50	9.00
AHDB9995 low	-	-	**6.74**	**6.97**	**7.20**	8.30	8.91
Wing-P	Gamit 36 CS	-	**7.13**	**6.50**	**6.50**	**7.38**	**7.38**
-	Wing-P + Gamit 36 CS inter-row	-	**6.75**	**7.25**	**7.50**	8.00	8.75
Stomp Aqua	Gamit 36 CS	-	**7.33**	**6.65**	**5.57**	**6.53**	**6.63**
-	Stomp Aqua + Gamit 36 CS inter-row	-	**7.75**	**7.75**	**7.75**	8.50	9.00
Stomp Aqua + Gamit 36 CS + AHDB9947	-	-	**5.66**	**4.65**	**3.90**	**5.53**	**5.30**
Wing-P	AHDB9987	-	**5.75**	**5.25**	**4.75**	**6.25**	**6.50**
-	AHDB9987 + Gamit 36 CS	-	**5.62**	**6.71**	**6.76**	**7.84**	8.12
-	AHDB9987 + Flexidor	-	**4.75**	**3.00**	**3.50**	**4.00**	**4.75**
-	AHDB9987 + Flexidor + Gamit 36 CS	-	**4.75**	**4.25**	**4.00**	**6.25**	**6.00**
-	AHDB9985 + Flexidor	-	**5.50**	**5.50**	**6.00**	**6.75**	**6.50**
-	AHDB9985 + Flexidor + Gamit 36 SC	-	**5.75**	**4.50**	**5.00**	**6.00**	**6.50**
-	Flexidor + Gamit 36 CS	Shark	**6.75**	**6.25**	**6.50**	**5.75**	**6.75**
		F prob value	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
		d.f.	**56**	**57**	**57**	**57**	**57**
		S.E.D.	**0.583**	**0.780**	**0.912**	**0.859**	**0.772**
		L.S.D.	**1.168**	**1.562**	**1.826**	**1.720**	**1.546**
		Mean	**6.64**	**6.19**	**6.19**	**7.03**	**7.24**

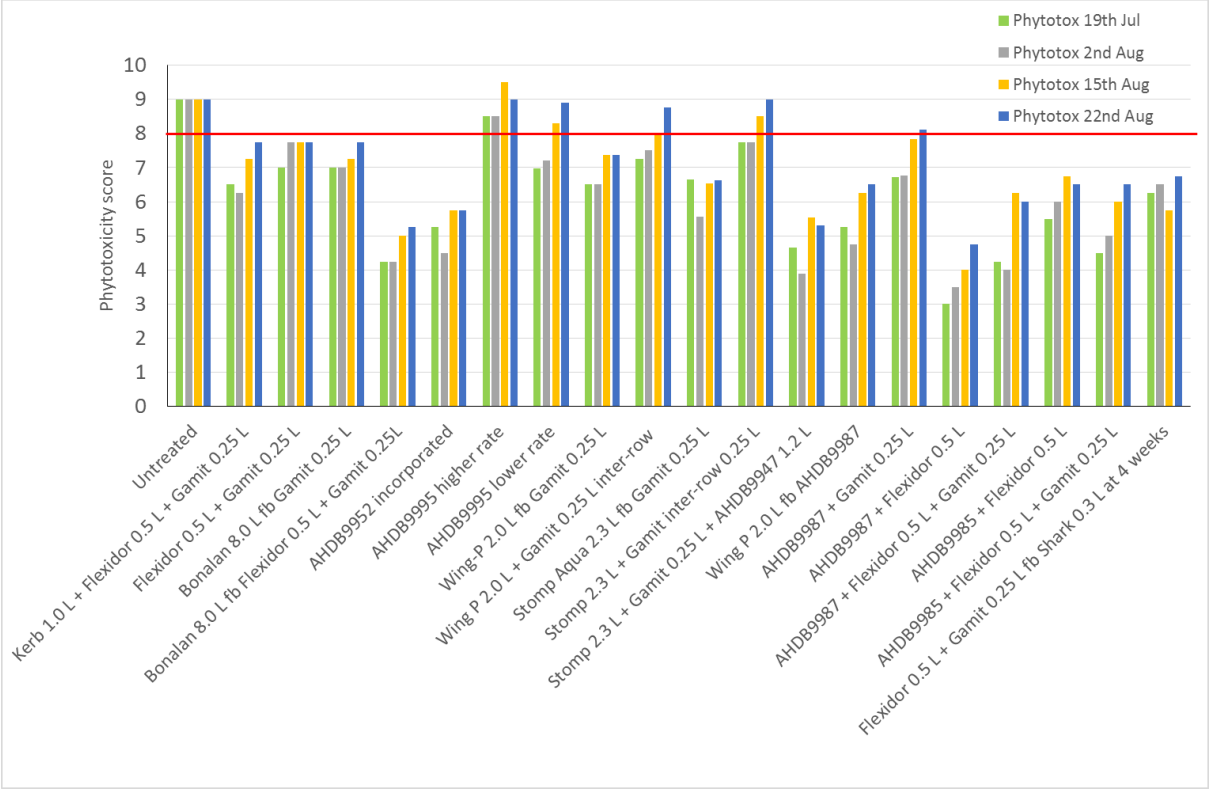


Figure 1 Mean phytotoxicity scores through the trial. (Scores 8 or above deemed acceptable damage). The score of 8 is indicated by the red line.

Weed control – mean percentage weed cover

The results for the mean percentage of weed cover per treatment are presented in Table 2 and Figures 2 to 3. Results significantly different from the untreated control are in **bold**.

Table 2 Mean percentage of weed cover. Treatments in **bold** are significantly different from the untreated control

	19th Jul		2nd Aug		15th Aug		22nd Aug		8th Sep	
	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans
Trt no										
1 + 2	8.74	2.31	34.61	32.26	64.79	81.86	70.62	88.99	75.00	93.31
3	**3.17**	0.31	**14.17**	5.99	**21.46**	13.38	**25.25**	18.20	**33.70**	30.85
4	**4.26**	0.55	**11.13**	3.73	**23.90**	16.42	**29.30**	23.94	**45.00**	50.07
5	**4.34**	0.57	**12.18**	4.45	**23.73**	16.20	**33.78**	30.91	**50.40**	59.29
6	**1.17**	0.04	**5.32**	0.86	**8.45**	2.16	**10.04**	3.04	**20.70**	12.51
7	**3.65**	0.41	**10.39**	3.25	**13.79**	5.68	**18.11**	9.67	**29.10**	23.68
8	8.09	1.98	**25.53**	18.57	62.70	78.97	64.61	81.61	70.90	89.30
9	9.19	2.55	34.07	31.39	66.12	83.62	72.82	91.27	72.80	91.26
10	**2.83**	0.24	**7.18**	1.56	**15.14**	6.82	**21.87**	13.88	**32.80**	29.37
11	8.34	2.11	**20.95**	12.78	**28.96**	23.44	**34.73**	32.46	**27.10**	20.82
12	**4.15**	0.53	**10.62**	3.39	**19.50**	11.14	**22.55**	14.70	**48.90**	56.71
13	9.19	2.55	**24.13**	16.72	**33.55**	30.55	**48.75**	56.53	**25.00**	17.88
14	**4.15**	0.53	**11.74**	4.14	**14.18**	6.00	**17.20**	8.74	**34.00**	31.27
15	**2.83**	0.24	**6.34**	1.22	**13.99**	5.84	**15.71**	7.33	**39.70**	40.86
16	**3.82**	0.44	**9.80**	2.89	**16.55**	8.12	**20.96**	12.80	**28.50**	22.73
17	**0.83**	0.02	**6.34**	1.22	**8.13**	2.00	**11.06**	3.68	**16.50**	8.03
18	**2.83**	0.24	**8.14**	2.01	**14.57**	6.33	**14.06**	5.90	**21.10**	13.00
19	**4.00**	0.48	**12.64**	4.79	**22.55**	14.70	**32.31**	28.58	**55.50**	67.99
20	**2.83**	0.24	**8.13**	2.01	**15.39**	7.04	**19.14**	10.75	**29.30**	24.00
21	**1.65**	0.08	**9.80**	2.89	**12.92**	5.00	**19.69**	11.36	**26.70**	20.23
F pr value	**<0.001**		**<0.001**		**<0.001**		**<0.001**		**<0.001**	

d.f.	**57**		**57**		**57**		**57**		**57**	
S.E.D.	**1.294**		**2.980**		**4.489**		**5.692**		**6.49**	
L.S.D.	**2.591**		**5.968**		**8.993**		**11.398**		**13.00**	

Figure 2 Mean percentage weed cover at four weeks after the post-planting application timing. P <0.001, s.e.d. = 2.980, l.s.d. = 5.968

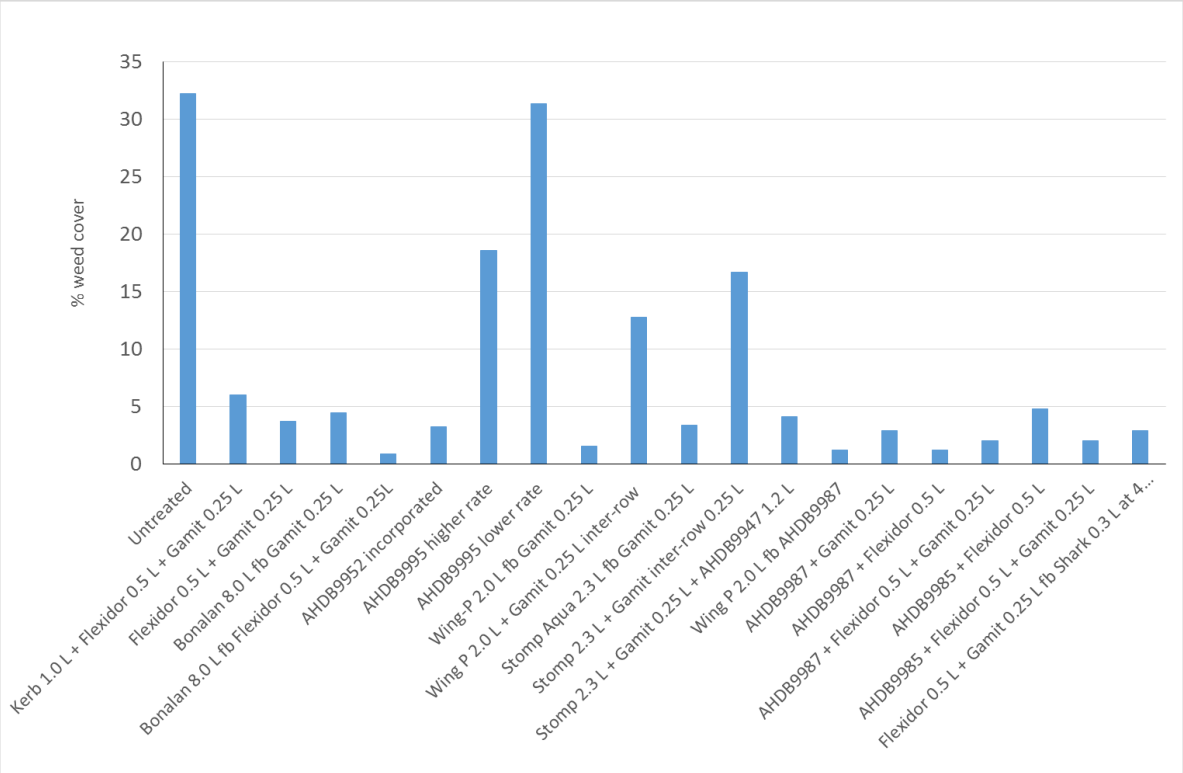
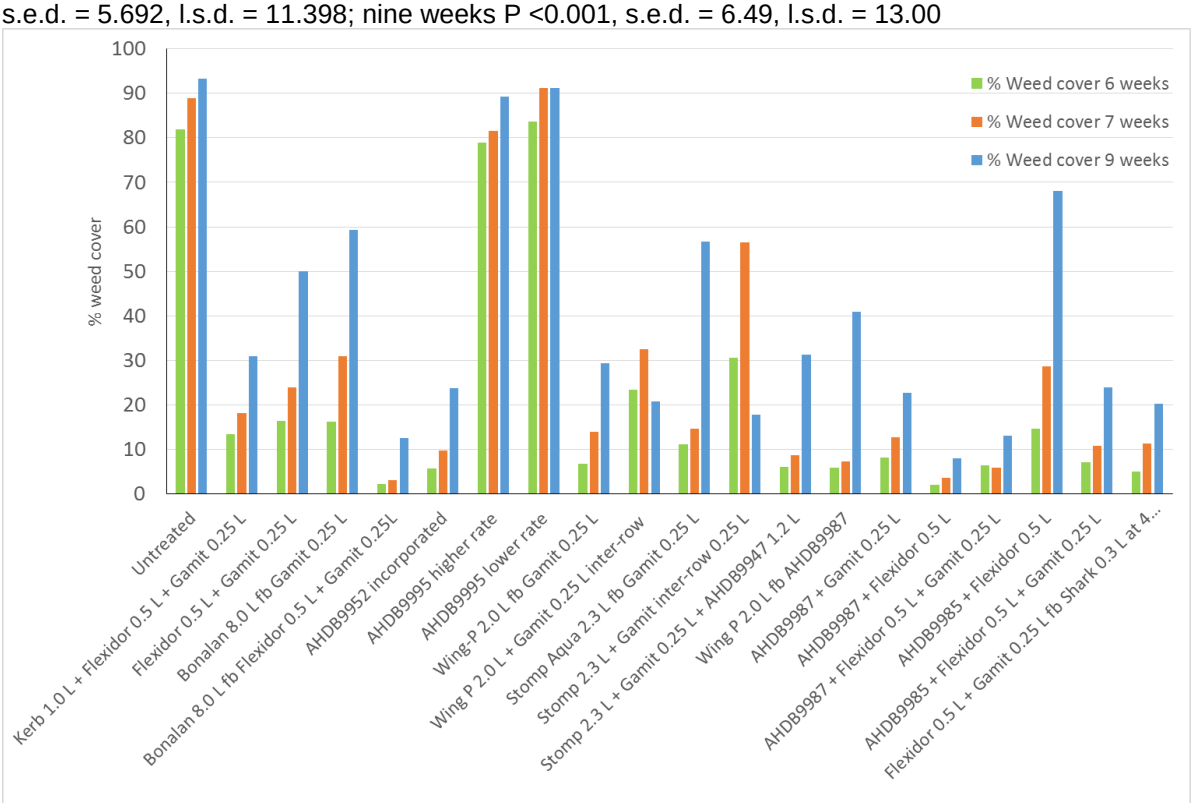


Figure 3 Mean percentage weed cover at six, seven and nine weeks after the post-planting application timing. Six weeks P <0.001, s.e.d. = 4.489, l.s.d. = 8.993; seven weeks P <0.001, s.e.d. = 5.692, l.s.d. = 11.398; nine weeks P <0.001, s.e.d. = 6.49, l.s.d. = 13.00



Weed control – % reduction in weed compared to untreated (Abbotts formula)

Table 3 Percentage reduction in weed cover using Abbotts formula

		Date	19-Jul	2-Aug	15-Aug	22-Aug	8-Sep
Timing A + B	**Timing C**	**Timing D**					
-	Kerb + Flexidor + Gamit 36 CS	-	86.77	81.43	83.66	79.55	66.94
-	Flexidor + Gamit 36 CS	-	76.10	88.45	79.94	73.10	46.34
Bonalan	Gamit 36 CS	-	75.20	86.19	80.21	65.27	36.46
Bonalan	Flexidor + Gamit 36 CS	-	98.19	97.34	97.36	96.58	86.59
AHDB9952	-	-	82.42	89.92	93.06	89.13	74.62
AHDB9995 high	-	-	14.21	42.44	3.53	8.29	4.30
AHDB9995 low	-	-	-10.42	2.71	-2.15	-2.56	2.20
Wing-P	Gamit 36 CS	-	89.48	95.16	91.67	84.40	68.52
-	Wing-P + Gamit 36 CS inter-row	-	8.92	60.36	71.37	63.52	77.69
Stomp Aqua	Gamit 36 CS	-	77.35	89.48	86.39	83.48	39.22
-	Stomp Aqua + Gamit 36 CS inter-row	-	-10.47	48.19	62.68	36.48	80.84
Stomp Aqua + Gamit 36 CS + AHDB9947	-	-	77.35	87.16	92.67	90.18	66.49
Wing-P	AHDB9987	-	89.48	96.22	92.87	91.76	56.21
-	AHDB9987 + Gamit 36 CS	-	80.78	91.02	90.08	85.62	75.64
-	AHDB9987 + Flexidor	-	99.09	96.22	97.56	95.86	91.39
-	AHDB9987 + Flexidor + Gamit 36 CS	-	89.48	93.79	92.27	93.37	86.07
-	AHDB9985 + Flexidor	-	78.96	85.15	82.04	67.88	27.14
-	AHDB9985 + Flexidor + Gamit 36 SC	-	89.48	93.80	91.40	87.92	74.28
-	Flexidor + Gamit 36 CS	Shark	96.39	91.03	93.89	87.23	78.32

Gross yield results

Gross yield was recorded by Barfoots staff for the eight treatments which were crop safe, or close to crop safe to the courgettes, and the results are presented in Table 4 and Figure 4.

All treatments except the lower rate of AHDB9995 gave higher yields than the untreated control. Three treatments gave significantly greater yields than the untreated control, these were the commercial standard, Flexidor 500 + Gamit 36 CS, and the two inter-row treatments; Stomp Aqua + Gamit 36 CS and Wing-P + Gamit 36 CS.

Table 4 Gross yield results presented as mean yield per five plants per plot, mean yield per plot, and as tonnes per hectare (multiple pickings, 30/08/2017 – 02/10/2017). Data not transformed. Treatments in **bold** are significantly different from the untreated control

Trt. No.	Timing A and B	Timing C	Gross yield per 5 plants (kg)	Yield per plant (kg)	Yield per ha (t/ha)
2	Untreated	-	7.03	1.407	17.37
4	Flexidor + Gamit 36 CS	-	**11.93**	**2.387**	**29.48**
5	Bonalan	Gamit 36 CS	8.42	1.683	20.79
8	AHDB9995 high	-	8.35	1.670	20.62
9	AHDB9995 low	-	3.26	0.652	8.05
10	Wing-P	Gamit 36 CS	9.38	1.875	23.16
11	Wing-P + Gamit 36 CS (inter-row)	-	**11.24**	**2.249**	**27.77**
13	Stomp Aqua + Gamit 36 CS (inter-row)	-	**12.12**	**2.423**	**29.93**
16	AHDB9987 + Gamit 36 CS	-	9.37	1.874	23.14
		F prob value	**<0.001**	**<0.001**	**<0.001**
		d.f.	**22**	**22**	**22**
		S.E.D.	**1.572**	**0.3143**	**3.882**
		L.S.D.	**3.259**	**0.6519**	**8.051**

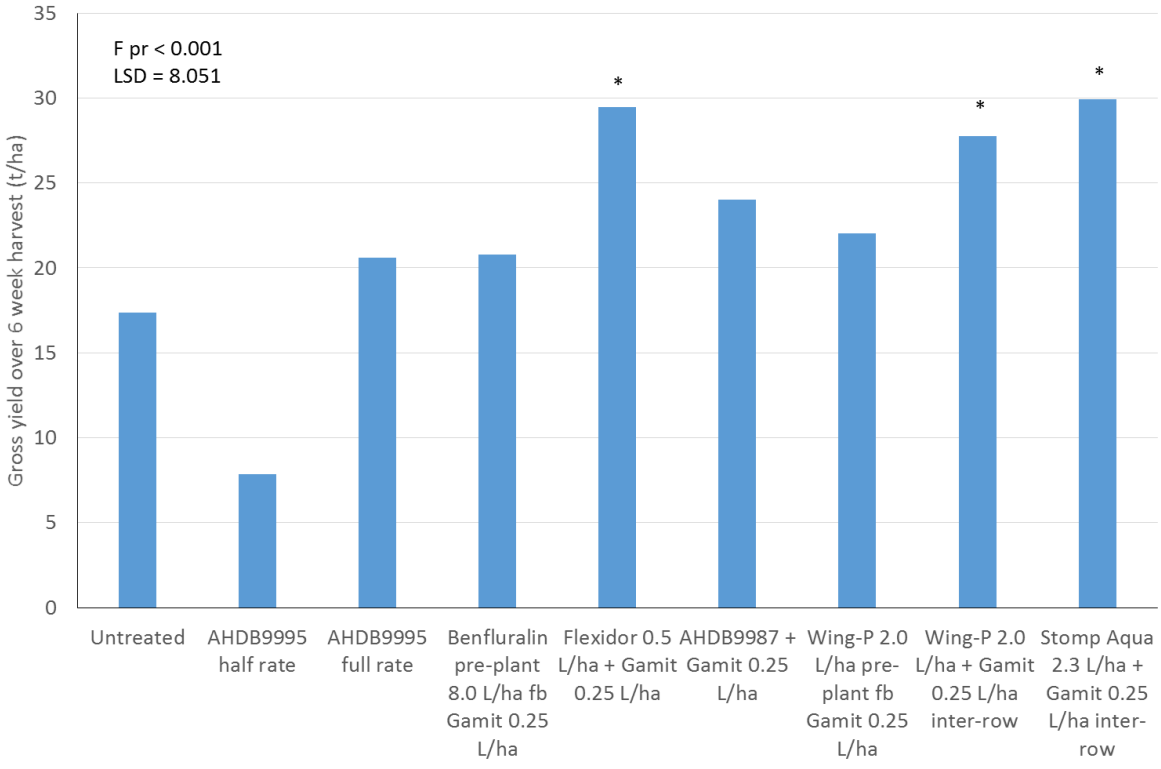


Figure 4 Means of gross yield in tons per hectare (multiple pickings, 30/08/2017 – 02/10/2017). Data not transformed.

Challenges during trial establishment
Establishment of the courgette crop was a challenge due to extreme dry conditions after planting, which was then followed by heavy showers. The crop did establish but it was initially slower to develop than usual.

In those plots which were rotavated, the cultivation led to a very soft seedbed for planting which is likely to have caused some plant loss in the Bonalan and AHDB9952 plots due to lack of soil/root contact, and these treatments warrant repeating. The soft seedbed and the tricky establishment conditions as described previously added together to lead to plant loss in these plots not caused by herbicide damage, as those plants which did establish in the Bonalan treatments were very healthy. In the AHDB9952 plots the plants which established were more stunted, but this treatment should also be repeated as the planting conditions confounded effects from the herbicide.

Discussion

All treatments except AHDB9995 significantly reduced the mean percentage weed cover ($p < 0.001$). Of the experimental treatments the greatest weed control (>90% reduction on 22 August pre-harvest) was achieved by five treatments; AHDB9987 tank-mixed with Flexidor or Flexidor + Gamit 36 CS; Stomp Aqua + Gamit 36 CS + AHDB9947 in a tank-mix pre-planting, Bonalan pre-planting followed by Flexidor + Gamit 36 CS, and Wing-P pre-planting followed by AHDB9987. However, these and many other treatments were not crop safe to the courgettes despite giving effective weed control.

Six treatments combined acceptable crop safety, or close to acceptable crop safety with reasonably effective weed control; the standard Flexidor + Gamit 36 CS, Bonalan or Wing-P applied at a reduced rate pre-planting followed by Gamit 36 CS post-planting, Wing-P or Stomp Aqua applied at reduced rates inter-row with Gamit 36 CS post-planting, and AHDB9987 in a tank-mix with Gamit 36 CS applied post-planting.

All treatments except the lower rate of AHDB9995 gave higher yields than the untreated control, in those that were assessed. Three treatments gave significantly greater yields than the untreated control, these were the commercial standard, Flexidor + Gamit 36 CS, and the two inter-row treatments; Stomp Aqua + Gamit 36 CS and Wing-P + Gamit 36 CS.

Despite giving poor weed control in this trial AHDB9995 should not be overlooked for further work as it gives useful control of annual meadow grass, black-bindweed, black-grass, knotgrass, pale persicaria, small nettle and wild oat which have been reported as problematic by growers. The weed species present in this trial would not have been well controlled by AHDB9995, as the main species were fat-hen and barnyard grass which are only moderately susceptible to this herbicide. Therefore further work is required with AHDB9995 to find suitable tank-mix partners to cover a wider weed spectrum.

The standard treatments performed as expected and were comparable to commercial practice. There were no issues with mixing or application of any products. No wetters were used.

Conclusions

- Wing-P or Stomp Aqua applied inter-row in a tank-mix with Gamit 36 CS gave improved weed control compared to the current standard, was crop safe, and gave equivalent yields to the current standard.
    - An application for an EAMU for Wing-P for inter-row use in courgettes has been submitted.
- AHDB9987 applied in a tank mix with Gamit 36 CS post-planting shows promise in controlling weeds in courgettes with no phytotoxic effects in this trial.
- AHDB9995 and Bonalan pre-planting followed by Gamit 36 CS were safe to the courgettes, but gave poor weed control. Tank-mixing or being included in sequence

with other products could improve the range of weed species controlled. Further work is needed to investigate possible safe product combinations.

- Further studies should also be repeated on the newer products Bonalan and AHDB9987.

Acknowledgements

Barfoots farm team, particularly Jim Smith and Neil Cairns

Appendix

a. Crop diary – events related to growing crop

Crop	Cultivar	Sowing date	Row width (m)
Courgettes	Kronos	4 July 2017	0.60

Previous cropping

Year	Crop
2016	Sweetcorn
2015	N/D

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

Date	Product	Rate	Unit
15/06/2017	Digestate V2	50.0	m^3/ha
05/08/2017	Calcium Ammonium Nitrate	356.154	kg/ha
04/09/2017	Nutriphite Excel	2.0	L/ha
04/09/2017	Headland Carnival	5.0	L/ha
12/09/2017	Headland Carnival	4.0	L/ha
12/09/2017	Headland Complex	4.0	kg/ha
19/09/2017	Headland Carnival	4.0	L/ha
19/09/2017	Headland Complex	4.0	kg/ha
19/09/2017	Nutriphite Excel	2.0	L/ha

Pesticides applied to trial area

Date	Product	Rate	Unit
17/06/2017	Azural	2.0	L/ha
17/06/2017	Chex	0.1	L/ha
12/09/2017	Signum	1.5	kg/ha
19/09/2017	Takumi SC	0.15	L/ha

Details of irrigation regime

Date	Type, rate and duration	Amount applied (mm)
5 July 2017	Overhead gun	10mm
11 July 2017	Overhead gun	10mm

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

Date	Event
03/07/2017	Trial marked out and Treatment A and B applied pre-planting, then Treatment A plots rotovated.
04/07/17	Markers removed Field planted by grower and marked out again
05/07/2017	Treatment C applied
13/07/2017	Crop safety assessed
19/07/2017	Weed levels and crop safety assessed Temp and RH data logger set up in centre of site.
01/08/2017	Treatment D applied
02/08/2017	Weed levels and crop safety assessed
15/08/2017	Weed levels and crop safety assessed
22/08/2017	Weed levels and crop safety assessed
08/09/2017	Weed levels assessed
30/08/2017 to 02/10/2017	Yield assessed by Barfoots staff (number of courgettes, size and weight)
04/10/2017	Trial area cleared after harvest

c. Table showing climatological data during study period – air max, air min and rainfall. Rainfall is only available from when the weather station was put out in the field by Barfoots. *Approx Rainfall after drilling was communicated by the farm manager, hence this figure

Date	Temperature ^{o}C (minimum)	Temperature ^{o}C (maximum)	Rainfall (mm)
11/07/2017	21.0	21.0	25.0*
12/07/2017	20.0	24.5	No data
13/07/2017	19.5	26.5	No data
14/07/2017	18.5	25.5	No data
15/07/2017	18.5	25.0	No data
16/07/2017	18.5	22.0	No data
17/07/2017	14.5	25.5	No data
18/07/2017	16.0	35.0	No data
19/07/2017	19.0	25.5	No data
20/07/2017	17.5	21.0	No data
21/07/2017	15.0	19.5	No data
22/07/2017	14.0	21.0	No data
23/07/2017	9.5	18.5	No data
24/07/2017	14.0	19.5	No data
25/07/2017	11.5	20.5	No data
26/07/2017	13.5	22.0	3.24
27/07/2017	15.0	19.0	0.00

Date	Temperature ºC (minimum)	Temperature ºC (maximum)	Rainfall (mm)
28/07/2017	15.5	19.5	1.24
29/07/2017	15.5	18.5	6.00
30/07/2017	14.5	18.5	4.00
31/07/2017	15.0	19.0	0.00
01/08/2017	12.0	20.0	0.00
02/08/2017	15.5	20.0	4.15
03/08/2017	15.5	18.0	3.75
04/08/2017	15.5	19.5	0.60
05/08/2017	13.5	19.5	0.75
06/08/2017	9.0	20.5	0.00
07/08/2017	14.5	19.5	0.00
08/08/2017	12.5	20.0	0.00
09/08/2017	11.5	20.0	13.5
10/08/2017	12.0	16.5	0.00
11/08/2017	8.5	21.5	0.75
12/08/2017	15.5	20.0	0.00
13/08/2017	12.5	22.0	0.00
14/08/2017	8.5	21.5	0.00
15/08/2017	14.0	22.5	0.00
16/08/2017	10.5	24.5	0.00
17/08/2017	16.0	22.0	2.15
18/08/2017	15.5	22.5	0.00
19/08/2017	13.5	21.5	1.15
20/08/2017	10.0	22.5	7.15
21/08/2017	14.5	22.0	0.55
22/08/2017	17.0	21.5	0.00
23/08/2017	17.5	21.5	0.00
24/08/2017	12.0	22.5	0.00
25/08/2017	9.5	22.0	0.00
26/08/2017	12.0	23.5	0.00
27/08/2017	12.5	24.0	0.00
28/08/2017	12.5	27.0	0.00
29/08/2017	14.0	26.0	0.00
30/08/2017	14.5	28.5	3.15
31/08/2017	7.0	14.5	0.15
01/09/2017	8.5	21.0	0.00
02/09/2017	9.0	23.5	0.00
03/09/2017	9.5	22.0	4.00
04/09/2017	14.0	17.5	3.50
05/09/2017	16.5	19.5	1.00
06/09/2017	12.5	19.0	0.00
07/09/2017	11.5	19.5	0.50
08/09/2017	15.0	20.0	0.00
09/09/2017	10.5	17.0	1.50

Date	Temperature ºC (minimum)	Temperature ºC (maximum)	Rainfall (mm)
10/09/2017	7.0	18.5	1.50
11/09/2017	13.0	17.5	1.25
12/09/2017	11.0	18.5	3.75
13/09/2017	13.0	18.5	0.25
14/09/2017	8.5	18.0	3.25
15/09/2017	5.0	19.0	3.00
16/09/2017	6.0	19.0	3.50
17/09/2017	6.0	19.5	0.00
18/09/2017	7.0	17.5	2.50
19/09/2017	7.0	19.5	0.25
20/09/2017	9.5	17.0	0.00
21/09/2017	14.0	18.0	1.40
22/09/2017	4.5	17.5	0.00
23/09/2017	11.5	19.5	0.00
24/09/2017	11.5	21.0	1.50
25/09/2017	15.0	20.5	5.25
26/09/2017	12.5	17.5	0.25
27/09/2017	12.5	21.5	14.00
28/09/2017	15.0	21.5	1.30
29/09/2017	13.0	20.5	3.50
30/09/2017	11.0	19.0	4.00
01/10/2017	12.5	17.5	3.00
02/10/2017	14.0	17.5	0.20
03/10/2017	7.5	18.5	0.75
04/10/2017	7.0	17.5	7.20

d. Photos of the trial site and to illustrate crop damage scores

Trial site just before harvest.

Photos to illustrate crop damage

		
Unacceptable stunting from Stomp Aqua pre-planting + Gamit 36 CS applied post-planting (scored 6.6)	**Stunting Wing-P pre-planting + Gamit 36 CS applied post-planting (Scored 7.4, so just under acceptable)**	**Stomp Aqua + Gamit 36 CS applied as a shielded inter-row spray showing no crop effect – score 9**

e. 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
Biologicals and Semiochemicals
Stored Crops

Date of issue: 16 December 2016
Effective date: 5 December 2016
Expiry date: 17 March 2018

Certification Number
ORETO 374

Signature R Brown
Authorised signatory

HSE
Chemicals Regulation Division

Department of
Agriculture and
Rural Development