Project title:	**Brassicas - Post-plant herbicide screen on kale and collards**
Project number:	FV 462
Project leader:	Angela Huckle, ADAS
Report:	Annual Report 2019
Previous report:	N/A
Key staff:	NIAB, PGRO, ADAS, Duchy College
Location of project:	Elsoms Trial Ground, Spalding. Lincs
Industry Representative:	Andy Richardson, Allium & Brassica Centre Will Illiffe, Southern England Farms
Date project commenced:	01 April 2019
Date project completed (or expected completion date):	31 Mar 2020

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The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

Technology transfer

Updates of trial data were circulated to levy payers by AHDB Horticulture and to agchem companies who supported the trials with samples of products FOC.

Knowledge exchange events were also hosted on these occasions:

1. Elsoms variety field open day in Lincs – 9/10 October 2019
2. Presentation to the Brassica Growers Association – 8 October 2019
3. SW Brassica Trials presentation evening in Cornwall – 15 January 2020
4. Hutchinsons Vegetable Agronomy Update, Lincs – 21 January 2020

These events were well attended by a number of growers, agronomists, research providers, and seed producers etc.

Trials and brassica related updates are regularly featured on social media through twitter @AHDB_Hort @angela_huckle @ADAS_Hortic @ADAS_Group @BritishGrowers with a combined following of over 19,000 users.

BGA newsletters produced by AHDB are also used to circulate key dates and information.

Final Trial Report

Trial code:	FV 462
Title:	**Horticulture Strategic Centres for Field Vegetables – Brassicas (post-plant)**
Crop	Group: field vegetables – Brassicas (collard greens & kale)
Target	General broadleaf weeds and grasses, 3WEEDT EPPO1/089(3) Weeds in leafy and brassica vegetables
Lead researcher:	Angela Huckle
Organisation:	RSK ADAS
Period:	1st April 2019 – 31st December 2019
Report date:	4th May 2020
Report author:	Angela Huckle Emily Lawrence
ORETO Number: (certificate should be attached)	409

I the undersigned, hereby declare that the work was performed according to the procedures herein described and that this report is an accurate and faithful record of the results obtained

…… ……
…… ……
Date Authors signature

Post-planting herbicide screen of promising products from SceptrePlus over kale and collards

Trial Summary

Take Home Message

- Post-planting application of AHDB9887, Dow Shield or Lentagran appears safe and effective for weed control in **collards.**

- In the **kale** trial, AHDB9875, AHDB9917 or Dow Shield applied post-planting appear crop safe and offer useful weed control.

- There is a need to repeat the work to confirm crop safety in less confounding conditions.

Introduction

The limited range of herbicides currently available for use in brassica crops such as kale and collards leaves gaps in the weed control spectrum, and growers experience problems with a wide range of weeds. Broad leaved weeds remain a key concern for brassica growers, particularly fat-hen, red-shank, charlock and fumitory (AHDB Gap Analysis, 2016). In addition to having a short list of approved actives, only a small subset of these offer the longevity of control required to protect longer season brassicas, such as kale. A further challenge for authorisation of products in these minor crops is the availability of crop safety and efficacy data to guide growers with their use, as products are usually only trialled over the major brassica types such as cauliflower and headed cabbage.

In hand harvested crops such as brassicas, weeds are a physical impediment to those working in the crop, and species such as nettles can deter pickers. Weeds which obscure the crop further reduce harvesting efficiency; where excessive weeds mean heads are missed, harvested yields can be reduced by up to 30%. The increased humidity in the crop canopy can also increase the risk of disease, and weed seeds can contaminate the fresh product.

While mechanical hoeing can be successfully used as an alternative weed control method, it is limited by crop growth stage and ground conditions, if soil conditions are not suitable this approach cannot always be used. Therefore, further options for weed control in minor brassica crops are required.

The objective of these trials was to identify crop-safe and effective herbicides for weed control in kale and collards testing products which have been identified as promising from the SceptrePlus work. With the aim to expand the options available to kale and collard growers, and give growers of these crops further information on use of the products.

Method

The trials were sited at Elsoms Trial Ground in Lincolnshire. The trial field was planted on 1st August 2019, with collard greens (variety ‘Duncan’) and kale (variety ‘Oldenbor’).

Treatments were applied at two timings. The first were applied on 2nd September 2019 (BBCH17), with a second treatment applied to selected plots on 13th September (BBCH19). All treatments were applied with a 2 m boom, using a knapsack sprayer at 300 L/ha water volume. A randomised block design was used for the trial layout, with two replicates of twelve treatments, including an untreated control. There were twenty-four plots in total for each brassica cultivar, with each plot measuring 2 m x 6 m.

The plots were assessed on four occasions (see 'Assessment details'), focussing on weed cover and species presence, and crop phytotoxicity (i.e. treatment safety). Assessments were carried out approximately two, four, eight, and twelve weeks after treatments were applied.

Results and discussion

The data has been statistically analysed but it should be highlighted that there were only two replicates in each of the trials and therefore the data is more of an indication of consistent trends when considering the results.

Collard greens:

Weed levels were moderate across the collard greens trial, with an average of 34.7% cover in the untreated control at the final assessment, twelve weeks after post-planting treatment application (Table 1).

Table 1. Summary of crop damage (0-10; 0 = no damage, 10 = complete crop death) and weed cover (back-transformed) from key assessment dates in collard greens trial. Scores significantly lower than that of the untreated are starred.

Treatment (rate)	Mean crop damage (0-10)		Mean weed cover (%)			
			4 weeks		12 weeks	
	4 weeks	12 weeks	Ang.	Back-trans	Ang.	Back-trans
Untreated	2.5	5.0	18.4	10.0	36.1	34.7
AHDB9875 (-)	3.5	4.5	10.8	*3.5	24.7	17.4
AHDB9917 (-)	3.5	5.0	11.5	*3.9	36.1	34.7
AHDB9874 (-)	5.0	6.5	6.9	*1.5	22.3	14.4
AHDB9874 x2 (-)	4.0	5.5	8.1	*2.0	18.3	9.8
AHDB9887 (½ N)	*0.0	3.5	15.7	7.3	39.8	41.0
AHDB9887 (N)	4.5	5.5	9.1	*2.5	30.3	25.4
Dow Shield (0.5 L/ha)	1.5	3.5	12.2	*4.5	33.1	29.8
AHDB9840 (½ N)	2.5	3.5	11.5	*3.9	26.7	20.2
AHDB9840 (N)	3.5	6.5	9.1	*2.5	29.5	24.3
AHDB9840 (2N)	4.0	4.5	8.1	*2.0	35.8	34.2
Lentagran (2.0 kg/ha)	2.5	4.0	12.9	*5.0	38.9	39.5
F prob. value	0.020	0.564	<0.001		0.248	
d.f.	11	11	11		11	
L.S.D.	2.234	3.519	3.534		17.29	

(N = label rate)

At four weeks after treatment, all treatments showed a significant reduction in % weed cover ($p < 0.001$), except for AHDB9887 at half label rate. However, by eight weeks after the application of the post-planting treatments, there were no significant differences in % weed cover observed between treatments and the untreated control. While not statistically significant, weed control by both AHDB9874 (single application) and AHDB9874 (double label rate application) was reduced, with the plots that received these treatments the only ones to show a net decrease in weed cover over the trial duration. AHDB9875 and AHDB9840 at ½ label rate and label rate also performed well, with little increase in % weed cover over the ten-week assessment period. Compared to the untreated control, these treatments reduced weed cover by 49.7% and 41.6% respectively.

However, while offering effective weed control, AHDB9874 (**Figure 1 and 2**) appeared to cause some phytotoxic effects (at both application rates), which first became apparent approximately four weeks after treatment application and persisted until the end of the trial. Collard greens treated with this product showed foliar distortion, with warped leaves and prominent veins, and were clearly smaller than the untreated crop. Similar foliar distortion was also noted for AHDB9875, AHDB9917, and AHDB9840 at double label rate (**Figure 3**). Where AHDB9840 was applied at the label rate, treated plots did not show foliar distortion, but the crop was small.

Figure 1. Foliar distortion following a single application of AHDB9874 to collard greens; pictured eight weeks after post-planting treatment.

Figure 2. (i) Effect on crop quality of single post-planting application of AHDB9874 on collard greens compared to **(ii)** untreated control (eight weeks after treatment application).

Figure 3. Effects caused by AHDB9840 when applied at double rate on the left, compared with the untreated plot on the right at eight weeks after treatment. Similar symptoms were also seen in those plots treated with AHDB9874, AHDB9917 and AHDB9875.

While several treatments caused notable phytotoxic effects, none emerged as significantly different from the untreated control in terms of crop safety due to difficult growing conditions at the trial site. It is important to note that conditions at the trial site were challenging, with heavy rain and grazing from pests including pigeons and rabbits. Compaction and waterlogging were also issues, causing crop growth to be stunted and vigour reduced—as reflected in the high phytotoxicity scores for the untreated controls. Identifying treatment effects was difficult, with multiple factors confounding the results of both trials but consistent effects were seen in the treatments noted above. Had the crop in the untreated plots not been subject to the adverse growing conditions, it is likely that the differences between these treatments and the untreated control would have been statistically significant.

Dow Shield and Lentagran appeared to be relatively crop safe treatments, but due to the size of the weeds at time of application this resulted in only 14.2% reduction in weed cover for Dow Shield and in the case of Lentagran an increase in weed cover, by twelve weeks after treatment application, compared to the untreated control. Both products currently have off-label approval for use on collard greens, and remain useful additions to spray programmes when applied at an appropriate timing. The trial indicates the importance of application timing for these products, as efficacy is reduced if the weeds are too large to control at the time of application.

Further work with AHDB9887 could be useful; this treatment appeared crop safe on collard greens when applied at the normal rate. AHDB9887 (N) showed a lower rate of weed cover increase than the untreated control, with plots that received this treatment having an average weed cover of 25.4% by twelve weeks after the post-planting treatment application, compared to an average weed cover of 34.7% in the untreated control. Additionally AHDB 9875 should not be discounted, as this product offered reasonable levels of weed control (17.4% cover at twelve weeks post application), and in the adjacent trial on kale showed no or very little crop effects and therefore would be worth testing again

Kale:
Weed levels were also moderate across the kale trial, with an average of 57.5% cover in the untreated control at the final assessment, twelve weeks after post-planting treatment application (Table 2).

Table 2. Summary of crop damage (0-10; 0 = no damage, 10 = complete crop death) and weed cover (back-transformed) from key assessment dates in kale trial. Scores significantly lower than that of the untreated are starred.

Treatment (rate)	**Mean crop damage** (0-10)		**Mean weed cover** (%)			
			4 weeks		**12 weeks**	
	4 weeks	**12 weeks**	**Ang.**	**Back-trans**	**Ang.**	**Back-trans**
Untreated	0.5	3.5	12.7	6.4	49.3	57.5
AHDB9875 (-)	0.0	3.0	10.5	3.3	28.3	22.5
AHDB9917 (-)	0.5	3.0	12.9	5.0	19.1	10.7
AHDB9874 (-)	*7.0	6.5	6.9	1.5	29.7	24.6
AHDB9874 x2 (-)	*6.5	6.5	5.7	1.0	17.9	9.4

AHDB9887	(½ N)	0.0	3.0	19.7	11.4	41.1	43.7
AHDB9887	(N)	0.0	6.5	9.1	2.5	33.1	29.8
Dow Shield	(0.5 L/ha)	0.5	2.0	13.3	5.3	33.3	30.2
AHDB9840	(½ N)	1.0	5.0	6.9	1.5	25.8	19.0
AHDB9840	(N)	*3.5	6.0	9.8	2.9	21.0	12.8
AHDB9840	(2N)	*6.0	4.5	6.9	1.5	31.0	26.5
Lentagran	(2.0 kg/ha)	0.0	4.0	15.7	7.3	37.8	37.5
	F prob. value	<0.001	0.205		0.117		0.166
	d.f.	11	11		11		11
	L.S.D.	1.348	3.896		9.235		21.40

(N = normal rate)

Across the four weed assessments, no treatment was found to offer a statistically significant difference to the untreated control in terms of weed control efficacy, though several treatments did appear to have a phytotoxic effect on the crop. Four weeks after the post-planting treatments were applied, the crop quality in plots treated with AHDB9874, AHDB9874 (x2), AHDB9840 (N), or AHDB9840 (2N) was significantly lower than in the untreated control. By the twelve-week assessment, these differences were no longer statistically significant, but the damage had persisted. At this final assessment, a treatment with AHDB9874 or AHDB9840 (at any of the rates trialed) appeared to cause foliar distortion. Kale treated with either of these products showed warped leaves (**Figure 4**), poor vigour (**Figure 5**), and stunted growth (**Figure 6**).

Figure 4. Foliar distortion following a double application of AHDB9874 to kale; pictured eight weeks after post-planting treatment application.

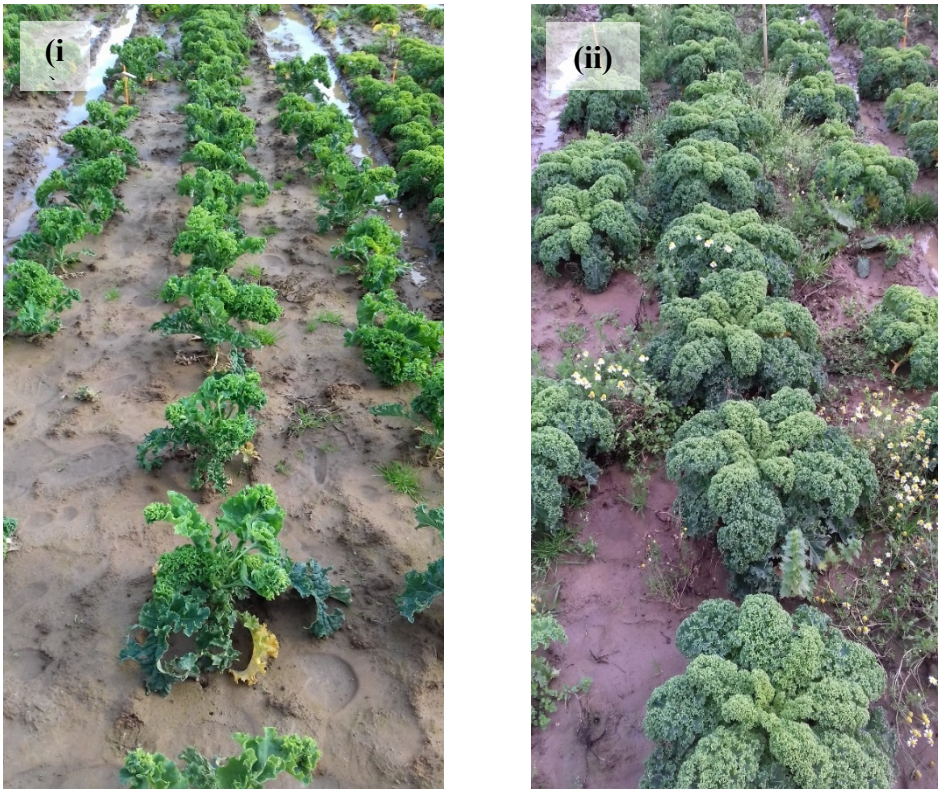

Figure 5. Effect on kale crop quality of a single post-planting application of AHDB9874 on kale **(i)**, compared to untreated control **(ii)** (eight weeks after treatment application).

Figure 6. Whole-plot view of effect of single post-planting application of AHDB9840 to kale **(i)**, compared to untreated control **(ii)**.

As with the collard greens, the phytotoxicity scores for this trial were confounded by the challenging growing conditions, including heavy rain and grazing from pests. At

trial set-up, it was not known that a soil pan ran through the centre of the trial area. This area of compaction and the waterlogging of the field impacted crop growth and vigour.

Of the remaining treatments, AHDB9875, AHDB9917, and Dow Shield appeared consistently safe on kale across the assessment timings. While AHDB9875 and Dow Shield offered a reasonable reduction in weed cover compared to the untreated control, weed control by AHDB9917 particularly stood out.

Conclusion

- Post-planting application of AHDB9887, Dow Shield or Lentagran appears safe and effective for weed control in **collards.**
- The manufacturer of AHDB9887 indicates that this product offers control of fat-hen and red-shank—both highlighted as particular problem weeds in brassica crops—as well as annual meadow-grass, black bindweed, black nightshade, chickweed, cranesbill, knotgrass, nettles, and speedwell.
- In the **kale** trial, AHDB9875, AHDB9917 or Dow Shield applied post-planting appear crop safe and offer useful weed control.
- Based on label recommendations, AHDB9875 offers control of fat-hen and red-shank—both highlighted as particular problem weeds in brassica crops—as well as annual meadow-grass, chickweed, cleavers, cranesbill, groundsel, knotgrass, mayweed, nettles, shepherd's purse, sow-thistle, and speedwell. AHDB9917 would give control of fat-hen, annual meadow-grass, and groundsel.
- There is a need to repeat the work to confirm crop safety in less confounding conditions.

Science Section

Objectives

Collard greens: To compare and demonstrate a number of new and novel herbicides at the post-planting application timing for selectivity (crop safety) and efficacy in collard greens.

Kale: To compare and demonstrate a number of new and novel herbicides at the post-planting application timing for selectivity (crop safety) and efficacy in kale.

Trial conduct

UK regulatory guidelines were followed but EPPO guideline took precedence. The following EPPO guidelines were followed:

Relevant EPPO guideline(s)		Variation from EPPO
EPPO PP1/135(4)	Phytotoxicity assessment	None
EPPO PP1/152(4)	Guideline on design and analysis of efficacy evaluation trials	None
EPPO PP1/181(4)	Conduct and reporting of efficacy evaluation trials including good experimental practice	None
EPPO PP1/214(3)	Principles of acceptable efficacy	None
EPPO PP1/224(2)	Principles of efficacy evaluation for minor uses	None
EPPO PP1/225(2)	Minimum effective dose	None

Test site

Item	Details
Location address	Field: Elsoms Trial Ground off A16 PE11 3JG Lincolnshire Grid reference: TF 25745 25975
Crop ('cultivar')	collard greens ('Duncan'), kale ('Oldenbor')
Soil or substrate type	Loamy and clayey soil of coastal flats with naturally high groundwater
Agronomic practice	See Appendix
Prior history of site	See Appendix

Trial design

Item	Details
Trial design:	Fully randomised block
Number of replicates:	2
Row spacing:	0.61 m (3 rows per 2 m wide plot)
Plot size: (w x l)	2 m x 6 m
Plot size:	12 m^2
Number of plants per plot:	approx. 33

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	AHDB9875	1200 24	3.00
3	AHDB9917	N/K	0.70
4	AHDB9874	2.5 12	0.25
5	AHDB9874	(2x) 2.5 (2x) 12	(2x) 0.25
6	AHDB9887	N/K	(kg/ha) 0.50
7	AHDB9887	N/K	(kg/ha) 1.00
8	Dow Shield	200	0.50
9	AHDB9840	2.5 60	0.50
10	AHDB9840	5 120	1.00
11	AHDB9840	10 240	2.00
12	Lentagran	900	(kg/ha) 2.00

Application details

	Timing A	Timing B
Application date	02/09/2019	13/09/2019
Time of day	11:00 – 13:00	12:30 – 13:00
Crop growth stage (Max, min average BBCH)	17	19
Application Method	spray	spray
Application Placement	foliar	foliar
Application equipment	AZO Plot	AZO Plot
Nozzle pressure (bar)	2.5	2.5
Nozzle type	Flat fan	Flat fan
Nozzle size	02-F110	02-F110
Application water volume (L/ha)	300	300
Temperature of air (°C)	18.0	18.0
Relative humidity (%)	55	49
Wind speed range (kph)	(N) 14.0	(N) 12.0
Dew presence (Y/N)	N	N
Temperature of soil (°C)	17.0	18.0
Wetness of soil	normal	normal
Cloud cover	75	70

	Timing A	Timing B
(%)		

Assessment details

Evaluation date	Evaluation Timing (DA)*	Evaluation type	What was assessed and how (e.g. dead or live pest; disease incidence and severity; yield, marketable quality)
17/09/2019	15	Efficacy Phytotox	Percentage of weed cover (whole plot score), weed species presence. Phyto (scale 0-10, 10 = Dead).
30/09/2019	28	Efficacy Phytotox	Percentage of weed cover (whole plot score), weed species presence. Phyto (scale 0-10, 10 = Dead).
28/10/2019	56	Efficacy Phytotox	Percentage of weed cover (whole plot score), weed species presence. Phyto (scale 0-10, 10 = Dead).
27/11/2019	86	Efficacy Phytotox	Percentage of weed cover (whole plot score), weed species presence. Phyto (scale 0-10, 10 = Dead).

* DA – days after Timing A application.

Statistical analysis

The trials had randomised block designs, each with treatments replicated twice. Each comprised twelve treatments, including an untreated control.

As the distribution of weeds was uneven across each trial—which is not unexpected in field situations—there was a need to transform this data prior to analysis. To determine treatment efficacy, an angular transformation was performed and the back transformed means presented, from which the % reduction in weeds was calculated using Abbotts formula.

All data were analysed by ANOVA using Genstat 16.0 by Emily Lawrence (ADAS).

Results

Conditions at the trial site were challenging, with heavy rain and grazing from pests including pigeons and rabbits. Compaction and waterlogging were issues, stunting crop growth and reducing vigour—the high phytotoxicity scores for the untreated controls reflect this. Identifying treatment effects was difficult, with multiple factors confounding the trials' results.

Phytotoxicity

Phytotoxicity was recorded using the following scale:

Crop tolerance score	Equivalent to crop damage (% phytotoxicity)
0	*(no damage)* 0%
1	10%
*2	20%
3	30%
4	40%

5	50%
6	60%
7	70%
8	80%
9	90%
10	*(complete crop kill)* 100%

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

Collard greens:

Phytotoxicity results are presented in Table 1 and Figure 7, and were scored according to the above scale.

Table 1. Mean crop phytotoxicity scores at two, four, eight, and twelve weeks after post-planting treatment application in collard greens trial. Values that are significantly different to untreated are starred.

Treatment (rate)	**Mean crop damage scores**			
	2 weeks	**4 weeks**	**8 weeks**	**12 weeks**
Untreated	0.0	2.5	2.5	5.0
AHDB9875 (-)	0.0	3.5	3.0	4.5
AHDB9917 (-)	0.0	3.5	3.0	5.0
AHDB9874 (-)	1.0	5.0	5.5	6.5
AHDB9874 x2 (-)	0.0	4.0	4.5	5.5
AHDB9887 (½ N)	0.0	*0.0	2.0	3.5
AHDB9887 (N)	1.5	4.5	4.0	5.5
Dow Shield (0.5 L/ha)	0.5	1.5	2.0	3.5
AHDB9840 (½ N)	0.0	2.5	4.0	3.5
AHDB9840 (N)	0.5	3.5	6.0	6.5
AHDB9840 (2N)	0.0	4.0	4.5	4.5
Lentagran (2.0 kg/ha)	0.5	2.5	3.0	4.0
F prob. value	0.697	0.020	0.145	0.564
d.f.	11	11	11	11
L.S.D.	1.797	2.234	2.918	3.519

(N = normal rate)

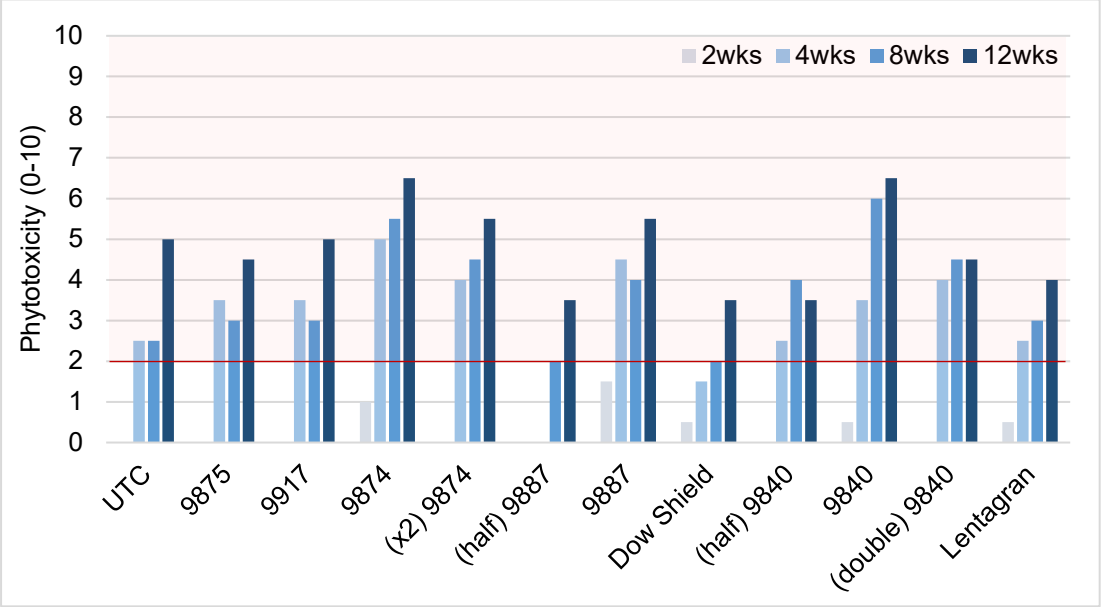

Figure 7. Mean phytotoxicity (0-10) at two, four, eight, and twelve weeks after post-planting

treatment application in collard greens trial. S cores ≤2 (marked by red line) deemed acceptable damage.

Kale:

Phytotoxicity results are presented in Table 2 and Figure 8, and were scored according to the above scale.

Table 2. Mean crop phytotoxicity scores at four, eight, and twelve weeks after post-planting treatment application in kale trial. Values that are significantly different to untreated are starred.

Treatment	(rate)	Mean crop damage scores			
		2 weeks	4 weeks	8 weeks	12 weeks
Untreated		1.5	0.5	4.0	3.5
AHDB9875	(-)	0.0	0.0	3.0	3.0
AHDB9917	(-)	0.0	0.5	3.0	3.0
AHDB9874	(-)	0.5	*7.0	6.5	6.5
AHDB9874 x2	(-)	0.0	*6.5	6.5	6.5
AHDB9887	(½ N)	0.0	0.0	2.0	3.0
AHDB9887	(N)	0.0	0.0	3.5	6.5
Dow Shield	(0.5 L/ha)	0.0	0.5	1.5	2.0
AHDB9840	(½ N)	1.0	1.0	3.0	5.0
AHDB9840	(N)	0.0	*3.5	5.5	6.0
AHDB9840	(2N)	0.5	*6.0	4.5	4.5
Lentagran	(2.0 kg/ha)	0.0	0.0	3.5	4.0
	F prob. value	0.667	<0.001	0.035	0.205
	d.f.	11	11	11	11
	L.S.D.	1.771	1.348	2.825	3.896

(N = normal rate)

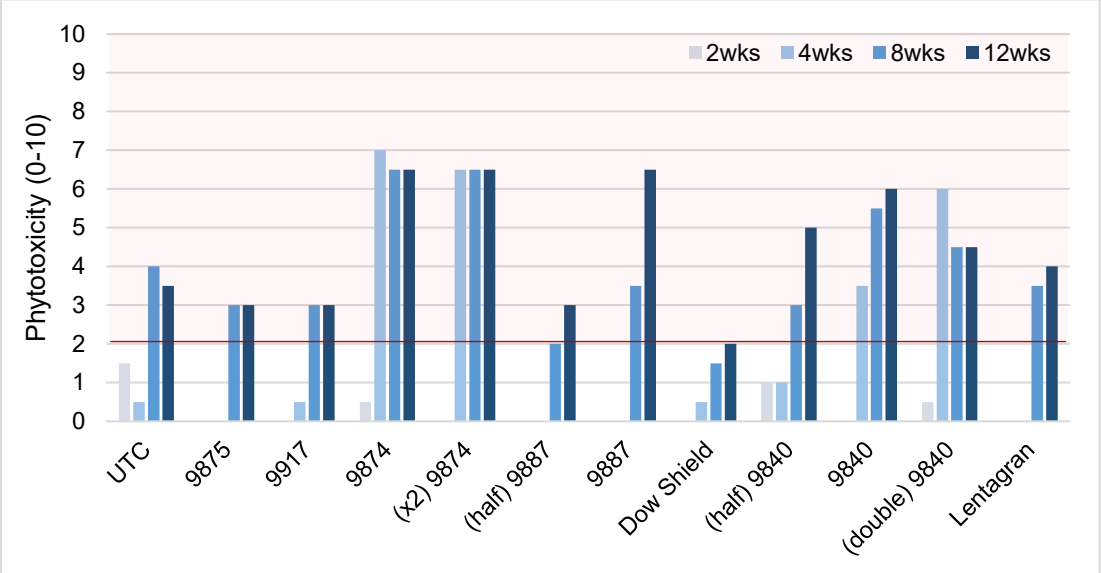

Figure 8. Mean phytotoxicity (0-10) at four, eight, and twelve weeks after post-planting treatment application in kale trial. Scores ≤2 (marked by red line) deemed acceptable damage.

Weed control – mean percentage weed cover

Collard greens:

Weed cover results are presented in Table 3 and Figure 9. These figures were used to calculate the percent reduction in weed cover compared to the untreated control (using Abbotts formula), and these values are listed in Table 4.

Table 3. Mean percentage weed cover values (transformed) at two, four, eight, and twelve weeks after post-planting treatment application in collard greens trial. Values that are significantly different to untreated are starred.

Treatment	(rate)	Mean weed cover (%)							
		2 weeks		4 weeks		8 weeks		12 weeks	
		Ang	Back-trans	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans
Untreated		27.4	21.1	18.4	10.0	32.9	29.5	36.1	34.7
AHDB9875	(-)	23.9	16.4	10.8	*3.5	22.5	14.6	24.7	17.4
AHDB9917	(-)	25.1	18.0	11.5	*3.9	36.5	35.3	36.1	34.7
AHDB9874	(-)	31.2	26.8	6.9	*1.5	19.1	10.7	22.3	14.4
AHDB9874 x2	(-)	26.6	20.0	8.1	*2.0	17.2	8.7	18.3	9.8
AHDB9887	(½ N)	24.6	17.3	15.7	7.3	32.6	29.1	39.8	41.0
AHDB9887	(N)	23.1	15.4	9.1	*2.5	23.4	15.8	30.3	25.4
Dow Shield	(0.5 L/ha)	24.6	17.3	12.2	*4.5	37.0	36.2	33.1	29.8
AHDB9840	(½ N)	25.1	18.0	11.5	*3.9	28.8	23.3	26.7	20.2
AHDB9840	(N)	17.3	8.9	9.1	*2.5	28.3	22.4	29.5	24.3
AHDB9840	(2N)	27.4	21.1	8.1	*2.0	32.5	28.8	35.8	34.2
Lentagran	(2.0 kg/ha)	27.4	21.1	12.9	*5.0	34.7	32.4	38.9	39.5
F prob. value			0.726		<0.001		0.323		0.248
d.f.			11		11		11		11
L.S.D.			12.35		3.534		18.29		17.29

(N = normal rate)

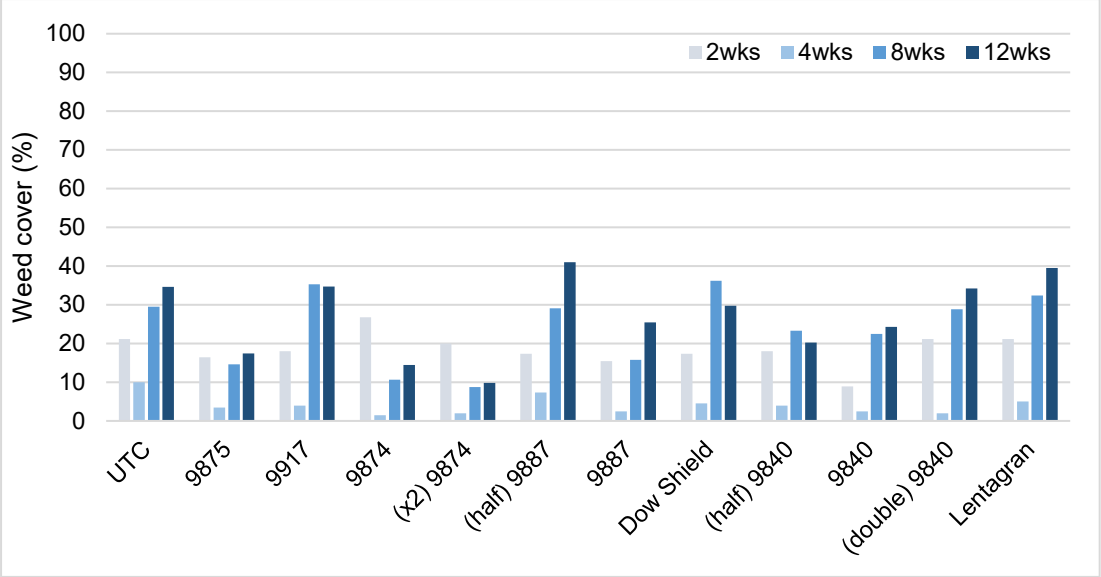

Figure 9. Mean weed cover (back transformed, %) at two, four, eight, and twelve weeks after post-planting treatment application in collard greens trial.

Table 4. Percentage reduction in weed cover compared to the untreated control at two, four, eight and twelve weeks after post-planting treatment application in collard greens trial.

Treatment	(rate)	Weed cover reduction (%)			
		2 weeks	4 weeks	8 weeks	12 weeks
AHDB9875	(-)	22.2	65.2	50.4	49.7
AHDB9917	(-)	14.5	60.6	-19.7	-0.1
AHDB9874	(-)	-26.8	85.4	63.8	58.4
AHDB9874 x2	(-)	5.3	80.0	70.5	71.6
AHDB9887	(½ N)	18.0	27.0	1.4	-18.1
AHDB9887	(N)	27.0	75.3	46.5	26.6
Dow Shield	(0.5 L/ha)	17.9	55.1	-22.8	14.2
AHDB9840	(½ N)	14.5	60.6	21.2	41.6
AHDB9840	(N)	57.9	75.3	24.0	29.9
AHDB9840	(2N)	0.0	80.0	2.4	1.4
Lentagran	(2.0 kg/ha)	0.0	50.0	-9.7	-13.9

(N = normal rate)

The initial weed burden in the collard greens trial was low, with a mean of 1.8% and little variation across the field (min. = 1.0%, max. = 2.5%). The change in weed cover from this baseline assessment to the final assessment was assessed. Most of the experimental herbicides showed a net increase in weed cover over this twelve week period (Figure 10) but reduced the rate of increase of weed cover relative to the untreated control. However, four treatments showed a higher rate of weed cover increase than the untreated control (AHDB9917, AHDB9887 (half rate), AHDB9840, and Lentagran). It should be noted that the weeds were a large rosette at application and this is too large for Lentagran to be effective. However, there were two

treatments—AHDB9874 (single application) and AHDB9874 (double application)—showed a net decrease in weed cover over the assessment period. These treatments, as well as AHDB9875 and AHDB9840 (half rate), performed particularly well.

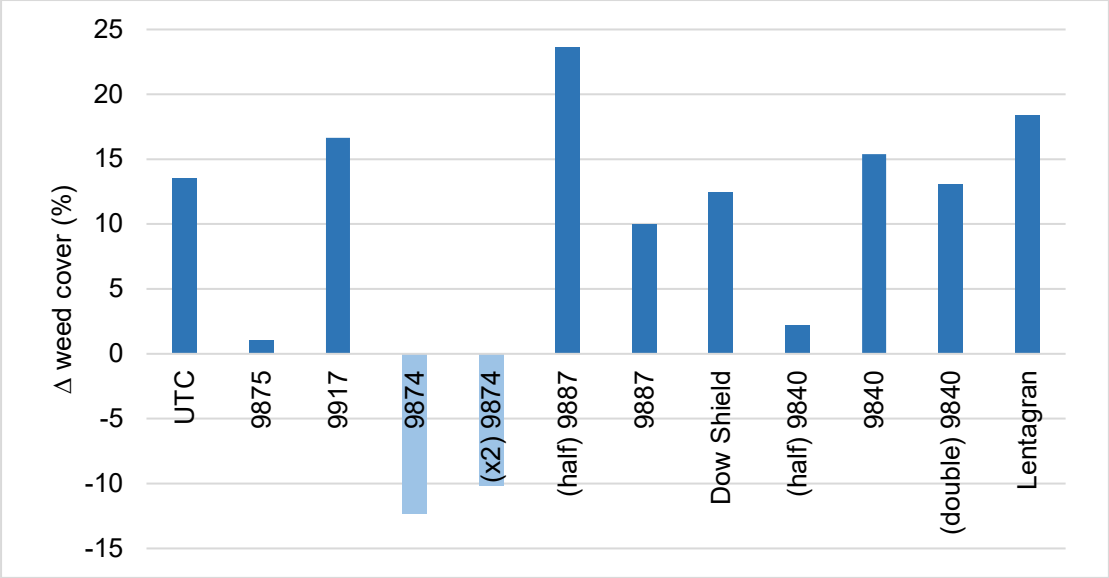

Figure 10. Percentage change in average weed cover over ten-week assessment period of collard greens trial. *(+ve change = weed cover increase, -ve change = weed cover decrease)*

Kale:

Weed cover results are presented in Table 5 and Figure 11. These figures were used to calculate the percent reduction in weed cover compared to the untreated control (using Abbotts formula), and these values are listed in Table 6.

Table 5. Mean percentage weed cover values (transformed) at two, four, eight, and twelve weeks after post-planting treatment application in kale trial.

Treatment	(rate)	Mean weed cover (%)							
		2 weeks		4 weeks		8 weeks		12 weeks	
		Ang	Back-trans	Ang	Back-trans	Ang	Back-trans	Ang	Back-trans
Untreated		31.7	27.6	12.7	6.4	45.0	50.0	49.3	57.5
AHDB9875	(-)	23.2	15.5	10.5	3.3	33.1	29.9	28.3	22.5
AHDB9917	(-)	22.2	14.3	12.9	5.0	22.5	14.6	19.1	10.7
AHDB9874	(-)	26.6	20.0	6.9	1.5	22.8	15.0	29.7	24.6
AHDB9874 x2	(-)	29.4	24.2	5.7	1.0	17.9	9.4	17.9	9.4
AHDB9887	(½ N)	23.1	15.4	19.7	11.4	37.2	36.6	41.1	43.7
AHDB9887	(N)	22.2	14.3	9.1	2.5	30.3	25.4	33.1	29.8
Dow Shield	(0.5 L/ha)	23.7	16.1	13.3	5.3	30.2	25.3	33.3	30.2
AHDB9840	(½ N)	23.9	16.5	6.9	1.5	26.7	20.2	25.8	19.0
AHDB9840	(N)	26.6	20.0	9.8	2.9	22.5	14.6	21.0	12.8
AHDB9840	(2N)	24.6	17.3	6.9	1.5	24.4	17.0	31.0	26.5
Lentagran	(2.0 kg/ha)	31.0	26.5	15.7	7.3	33.1	29.9	37.8	37.5
F prob. value			0.780		0.117		0.204		0.166
d.f.			11		11		11		11
L.S.D.			13.36		9.235		18.28		21.40

(N = normal rate)

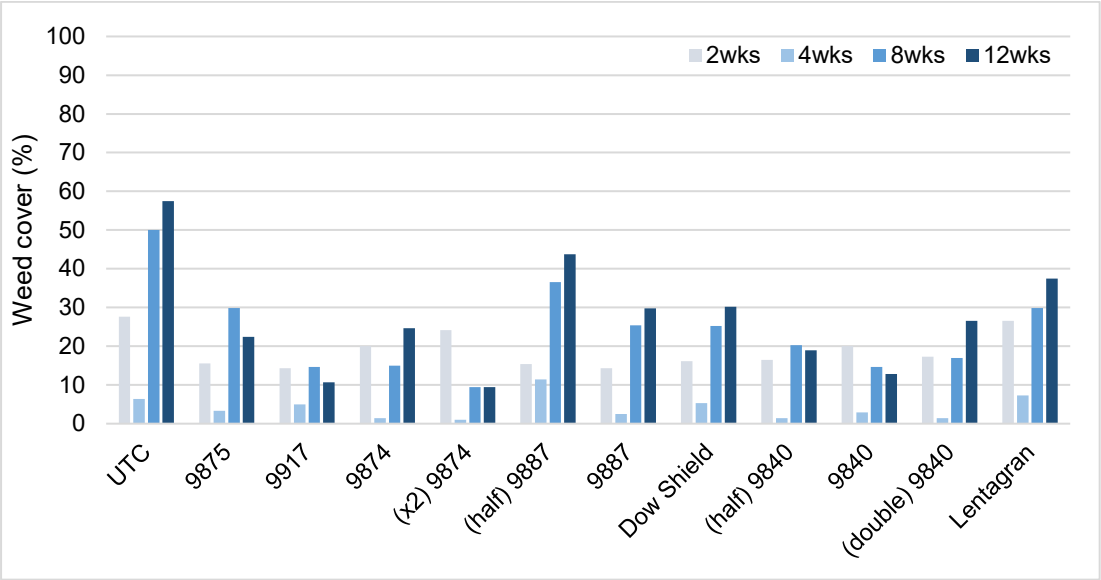

Figure 11. Mean weed cover (back transformed, %) at two, four, eight, and twelve weeks after post-planting treatment application in kale trial.

Table 6. Percentage reduction in weed cover compared to the untreated control at two, four, eight and twelve weeks after post-planting treatment application in kale trial.

Treatment	(rate)	Weed cover reduction (%)			
		2 weeks	4 weeks	8 weeks	12 weeks
AHDB9875	(-)	43.8	48.0	40.2	61.0
AHDB9917	(-)	48.3	22.8	70.7	81.4
AHDB9874	(-)	27.6	77.3	70.0	57.2
AHDB9874 x2	(-)	12.6	84.4	81.2	83.7
AHDB9887	(½ N)	44.2	-77.8	26.8	24.0
AHDB9887	(N)	48.3	61.4	49.1	48.3
Dow Shield	(0.5 L/ha)	41.6	17.7	49.5	47.5
AHDB9840	(½ N)	40.4	77.3	59.5	67.0
AHDB9840	(N)	27.6	54.5	70.7	77.8
AHDB9840	(2N)	37.3	77.3	66.0	53.9
Lentagran	(2.0 kg/ha)	4.0	-13.8	40.2	34.8

(N = normal rate)

The initial weed burden in the kale trial was low, with a mean of 1.9% and little variation across the field (min. = 1.5%, max. = 2.5%). The change in weed cover from this baseline assessment to the final assessment was assessed. Most treatments showed a net increase in weed cover over this period (Figure 12), but all reduced the rate of weed cover increase relative to the untreated control. Three treatments—AHDB9917, AHDB9874 (applied twice), and AHDB9840 (normal rate)—showed a net decrease in

weed cover over the assessment period. These treatments, as well as AHDB9875, AHDB9874, and AHDB9840 (half rate), performed particularly well.

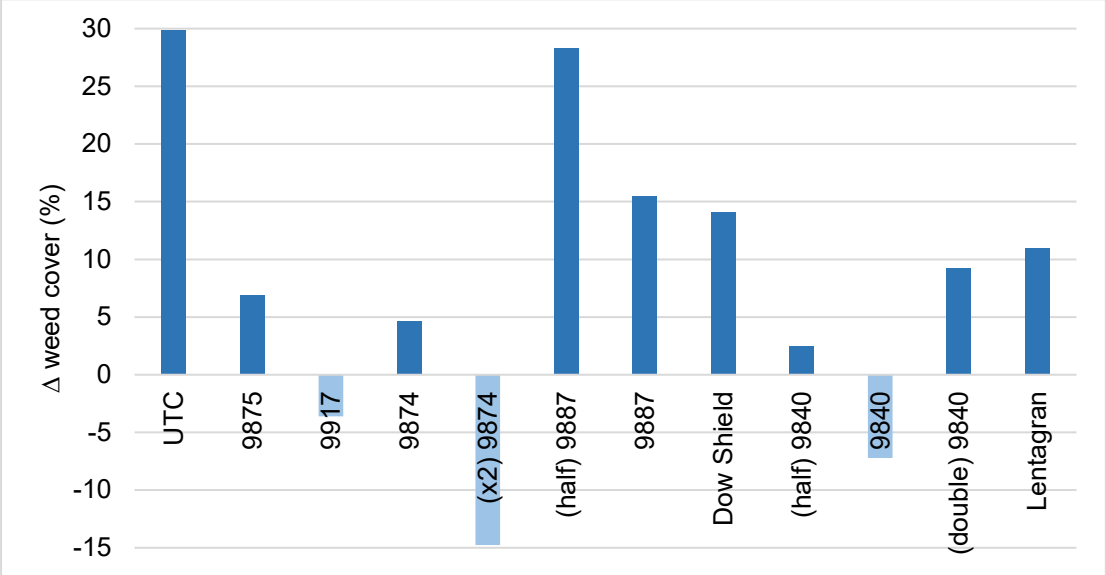

Figure 12. Percentage change in average weed cover over ten-week assessment period of kale trial. *(+ve change = weed cover increase, -ve change = weed cover decrease)*

Discussion

Collard greens

Weed levels were moderate across the collard greens trial, with an average of 34.7% cover in the untreated control at the final assessment, twelve weeks after post-planting treatment application.

At four weeks after treatment, all treatments showed a significant reduction in % weed cover ($p < 0.001$), except for AHDB9887 at half label rate. However, by eight weeks after the application of the post-planting treatments, there were no significant differences in % weed cover observed between treatments and the untreated control. While not statistically significant, weed control by both AHDB9874 (single application) and AHDB9874 (double label rate application) was reduced, with the plots that received these treatments the only ones to show a net decrease in weed cover over the trial duration. AHDB9875 and AHDB9840 at ½ label rate and label rate also performed well, with little increase in % weed cover over the ten-week assessment period. Compared to the untreated control, these treatments reduced weed cover by 49.7% and 41.6% respectively.

However, while offering effective weed control, AHDB9874 (**Figure 13 and 14**) appeared to cause some phytotoxic effects (at both application rates), which first became apparent approximately four weeks after treatment application and persisted until the end of the trial. Collard greens treated with this product showed foliar distortion, with warped leaves and prominent veins, and were clearly smaller than the untreated crop. Similar foliar distortion was also noted for AHDB9875, AHDB9917, and AHDB9840 at double label rate (**Figure 15**). Where AHDB9840 was applied at the label rate, treated plots did not show foliar distortion, but the crop was small.

Figure 13. Foliar distortion following a single application of AHDB9874 to collard greens; pictured eight weeks after post-planting treatment.

Figure 14. (i) Effect on crop quality of single post-planting application of AHDB9874 on collard greens compared to **(ii)** untreated control (eight weeks after treatment application).

Figure 15. Effects caused by AHDB9840 when applied at double rate on the left, compared with the untreated plot on the right at eight weeks after treatment. Similar symptoms were also seen in those plots treated with AHDB9874, AHDB9917 and AHDB9875.

While several treatments caused notable phytotoxic effects, none emerged as significantly different from the untreated control in terms of crop safety due to difficult growing conditions at the trial site. It is important to note that conditions at the trial site were challenging, with heavy rain and grazing from pests including pigeons and rabbits. Compaction and waterlogging were also issues, causing crop growth to be stunted and vigour reduced—as reflected in the high phytotoxicity scores for the untreated controls. Identifying treatment effects was difficult, with multiple factors confounding the results of both trials but consistent effects were seen in the treatments noted above. Had the crop in the untreated plots not been subject to the adverse growing conditions, it is likely that the differences between these treatments and the untreated control would have been statistically significant.

Dow Shield and Lentagran appeared to be relatively crop safe treatments, but due to the size of the weeds at time of application this resulted in only 14.2% reduction in weed cover for Dow Shield and in the case of Lentagran an increase in weed cover, by twelve weeks after treatment application, compared to the untreated control. Both products currently have off-label approval for use on collard greens, and remain useful additions to spray programmes when applied at an appropriate timing. The trial indicates the importance of application timing for these products, as efficacy is reduced if the weeds are too large to control at the time of application.

Further work with AHDB9887 could be useful; this treatment appeared crop safe on collard greens when applied at the normal rate. AHDB9887 (N) showed a lower rate of weed cover increase than the untreated control, with plots that received this treatment having an average weed cover of 25.4% by twelve weeks after the post-planting treatment application, compared to an average weed cover of 34.7% in the untreated control. Additionally AHDB 9875 should not be discounted, as this product offered reasonable levels of weed control (17.4% cover at twelve weeks post application), and

in the adjacent trial on kale showed no or very little crop effects and therefore would be worth testing again

Kale

Weed levels were also moderate across the kale trial, with an average of 57.5% cover in the untreated control at the final assessment, twelve weeks after post-planting treatment application

Across the four weed assessments, no treatment was found to offer a statistically significant difference to the untreated control in terms of weed control efficacy, though several treatments did appear to have a phytotoxic effect on the crop. Four weeks after the post-planting treatments were applied, the crop quality in plots treated with AHDB9874, AHDB9874 (x2), AHDB9840 (N), or AHDB9840 (2N) was significantly lower than in the untreated control. By the twelve-week assessment, these differences were no longer statistically significant, but the damage had persisted. At this final assessment, a treatment with AHDB9874 or AHDB9840 (at any of the rates trialed) appeared to cause foliar distortion. Kale treated with either of these products showed warped leaves (**Figure 16**), poor vigour (**Figure 17**), and stunted growth (**Figure 18**).

Figure 16. Foliar distortion following a double application of AHDB9874 to kale; pictured eight weeks after post-planting treatment application.

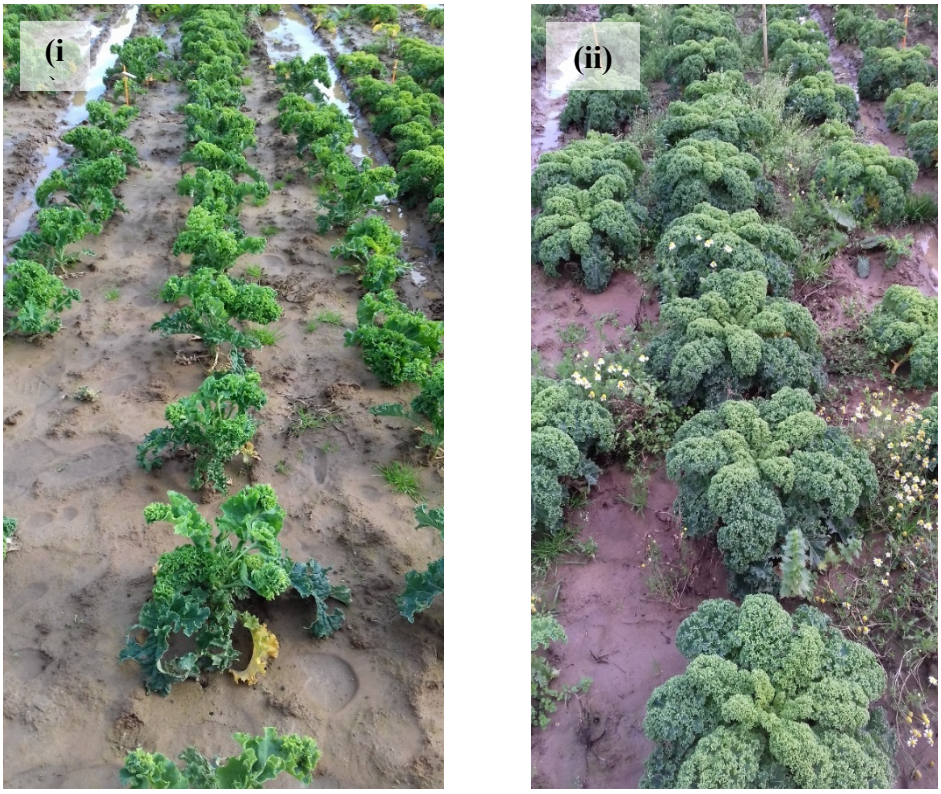

Figure 17. Effect on kale crop quality of a single post-planting application of AHDB9874 on kale **(i)**, compared to untreated control **(ii)** (eight weeks after treatment application).

Figure 18. Whole-plot view of effect of single post-planting application of AHDB9840 to kale **(i)**, compared to untreated control **(ii)**.

As with the collard greens, the phytotoxicity scores for this trial were confounded by the challenging growing conditions, including heavy rain and grazing from pests. At

trial set-up, it was not known that a soil pan ran through the centre of the trial area. This area of compaction and the waterlogging of the field impacted crop growth and vigour.

Of the remaining treatments, AHDB9875, AHDB9917, and Dow Shield appeared consistently safe on kale across the assessment timings. While AHDB9875 and Dow Shield offered a reasonable reduction in weed cover compared to the untreated control, weed control by AHDB9917 particularly stood out.

Conclusion

- Post-planting application of AHDB9887, Dow Shield or Lentagran appears safe and effective for weed control in **collards.**

- The manufacturer of AHDB9887 indicates that this product offers control of fat-hen and red-shank—both highlighted as particular problem weeds in brassica crops—as well as annual meadow-grass, black bindweed, black nightshade, chickweed, cranesbill, knotgrass, nettles, and speedwell.

- In the **kale** trial, AHDB9875, AHDB9917 or Dow Shield applied post-planting appear crop safe and offer useful weed control.

- Based on label recommendations, AHDB9875 offers control of fat-hen and red-shank—both highlighted as particular problem weeds in brassica crops—as well as annual meadow-grass, chickweed, cleavers, cranesbill, groundsel, knotgrass, mayweed, nettles, shepherd's purse, sow-thistle, and speedwell. AHDB9917 would give control of fat-hen, annual meadow-grass, and groundsel.

- There is a need to repeat the work to confirm crop safety in less confounding conditions.

Acknowledgements

AHDB for funding the work, and the crop protection companies for their financial contributions and provision of samples for the trials. Thanks too to Elsoms Seeds, who provided sites and crop for the trials, and to Carl Sharp of the Allium and Brassica Centre, for site management and treatment application.

Appendix

a. Crop diary – events related to growing crop

Crop	**Cultivar**	**Planting date**	**Row width** (m)
Collard greens	Duncan	01/08/2019	0.61 m
Kale	Oldenbor	01/08/2019	0.61 m

Previous cropping

Year	**Crop**
2018	PSB/cauliflower (half of the trial area)
2017	Rye (cover crop)
2016	Bare ground

Cultivations

Date	**Description**
Mar 2019	Power harrowed and rolled prior to planting.
Dec 2018	Subsoiled and winter ploughed.

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

Date	**Product**	**Rate** (kg/ha)
Mar 2019	Base fertiliser	250 kg/ha 10-15-21 + 20SO3
Mar 2019	Top dressing	80 kg/ha N 26N + 35SO3

Pesticides applied to trial area

Date	**Product**	**Rate** (L/ha)
15/10/2019	Biscaya	0.5 L/ha

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

	Date	**Event**
TRIAL 1	01/08/2019	Crop planted.
	02/09/2019	Application A spray.
	13/09/2019	Application B spray.
	17/09/2019	Assessment, two weeks after treatment (phyto/weeds).

	30/09/2019	Assessment, four weeks after treatment (phyto/weeds).
	28/10/2019	Assessment, eight weeks after treatment (phyto/weeds).
	27/11/2019	Assessment, twelve weeks after treatment (phyto/weeds).

c. Climatological data during study period from each site, including conditions prior to planting.

Date	Min. temp. (°C)	Max. temp. (°C)	Precip. (mm)
01/07/19	12	20	0
02/07/19	9	20	0
03/07/19	10	20	0
04/07/19	9	25	0
05/07/19	12	25	0
06/07/19	12	19	2
07/07/19	12	19	0
08/07/19	12	19	0
09/07/19	14	20	0
10/07/19	16	23	0
11/07/19	16	24	2
12/07/19	14	23	6
13/07/19	14	20	0
14/07/19	12	19	3
15/07/19	12	22	0
16/07/19	11	25	0
17/07/19	14	25	0
18/07/19	13	23	1
19/07/19	10	18	9
20/07/19	12	22	10
21/07/19	10	23	0
22/07/19	16	29	0
23/07/19	14	29	0
24/07/19	19	30	2
25/07/19	18	34	0
26/07/19	19	26	1
27/07/19	15	19	24
28/07/19	15	20	1
29/07/19	14	25	2
30/07/19	16	24	5
31/07/19	16	20	2
01/08/19	15	22	4
02/08/19	15	22	1
03/08/19	12	23	0
04/08/19	15	26	0
05/08/19	14	24	2
06/08/19	13	23	4
07/08/19	13	24	0
08/08/19	12	25	0
09/08/19	16	26	16
10/08/19	16	23	1
11/08/19	11	20	1
12/08/19	9	19	0
13/08/19	10	19	2
14/08/19	9	17	22
15/08/19	10	20	2
16/08/19	9	18	12
17/08/19	12	22	5
18/08/19	12	22	2
19/08/19	10	22	0

Date	Min. temp. (°C)	Max. temp. (°C)	Precip. (mm)
20/08/19	9	20	0
21/08/19	12	22	0
22/08/19	13	24	0
23/08/19	13	26	0
24/08/19	12	27	0
25/08/19	14	30	0
26/08/19	15	30	0
27/08/19	16	30	0
28/08/19	13	23	2
29/08/19	11	22	1
30/08/19	14	24	0
31/08/19	9	22	0
01/09/19	9	17	0
02/09/19	8	19	0
03/09/19	12	24	0
04/09/19	13	19	2
05/09/19	8	19	0
06/09/19	8	19	0
07/09/19	8	17	0
08/09/19	8	18	0
09/09/19	8	14	2
10/09/19	8	18	0
11/09/19	8	22	1
12/09/19	8	24	0
13/09/19	8	20	0
14/09/19	8	22	0
15/09/19	8	20	3
16/09/19	8	17	7
17/09/19	8	17	0
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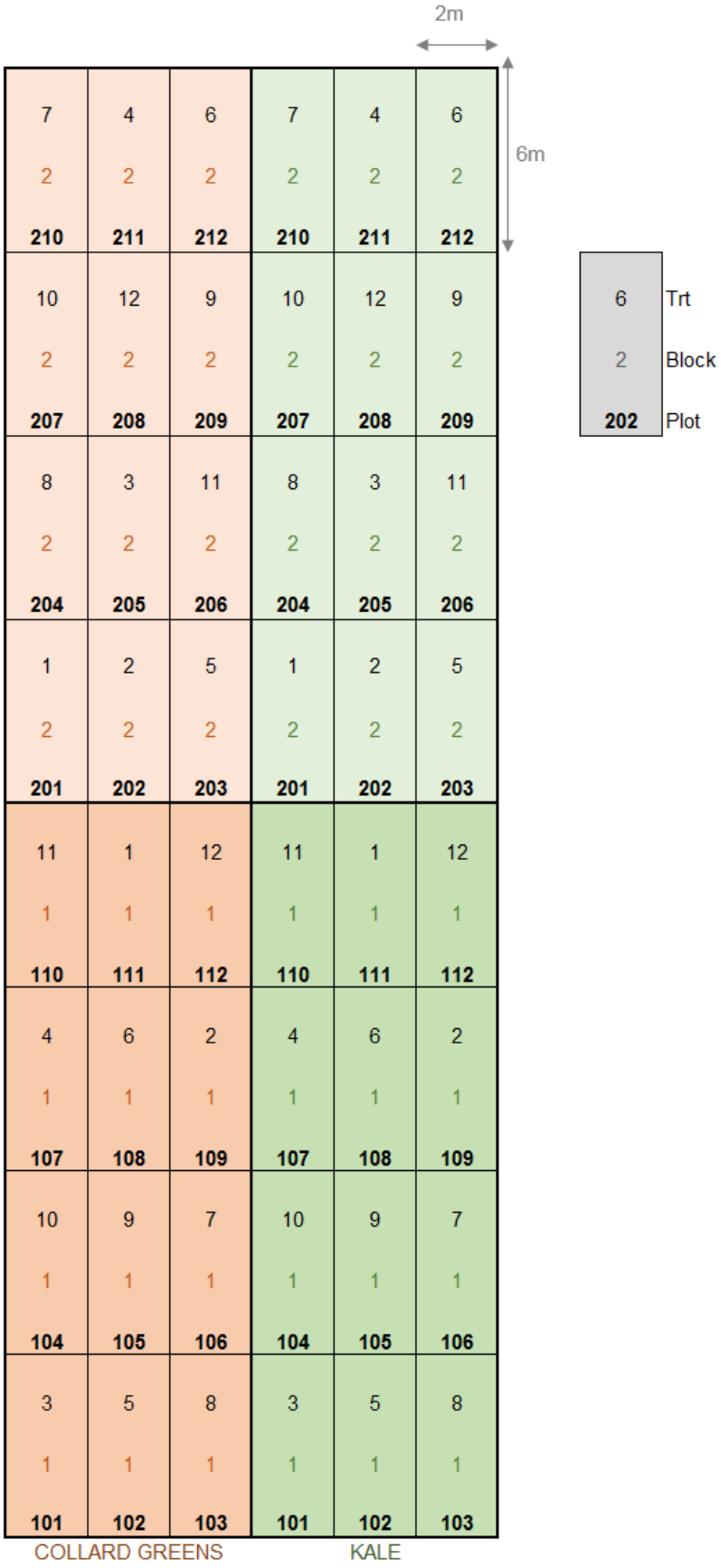
19/09/19	8	22	0
20/09/19	8	20	0
21/09/19	8	24	0
22/09/19	8	23	3
23/09/19	8	20	1
24/09/19	8	18	16
25/09/19	8	18	35
26/09/19	8	20	5
27/09/19	8	16	9
28/09/19	8	18	16
29/09/19	8	19	26
30/09/19	8	16	14
01/10/19	8	14	48
02/10/19	8	13	0
03/10/19	8	12	7
04/10/19	8	15	8
05/10/19	8	16	0
06/10/19	8	14	15
07/10/19	8	13	1
08/10/19	8	16	0

Date	Min. temp. (°C)	Max. temp. (°C)	Precip. (mm)
09/10/19	8	16	0
10/10/19	8	16	0
11/10/19	8	16	6
12/10/19	8	15	0
13/10/19	8	14	22
14/10/19	8	13	20
16/10/19	8	15	1
17/10/19	8	13	1
18/10/19	8	14	1
19/10/19	8	14	1
20/10/19	8	12	1
21/10/19	8	13	1
22/10/19	3	14	0
23/10/19	4	14	1
24/10/19	7	12	10
25/10/19	6	15	2
26/10/19	5	9	28
27/10/19	3	12	0
28/10/19	2	11	0
29/10/19	2	12	2
30/10/19	4	12	1
31/10/19	3	11	0
01/11/19	6	14	6
02/11/19	8	14	10
03/11/19	6	12	0
04/11/19	7	12	2
05/11/19	5	12	12
06/11/19	3	8	1
07/11/19	6	9	28
08/11/19	3	8	6
09/11/19	1	7	0
10/11/19	4	10	0
11/11/19	5	9	12
12/11/19	4	8	1
13/11/19	1	9	0
14/11/19	4	8	39
15/11/19	3	9	4
16/11/19	6	9	1
17/11/19	5	9	0
18/11/19	1	8	0
19/11/19	-3	5	0
20/11/19	0	7	0
21/11/19	2	7	0
22/11/19	6	9	2
23/11/19	7	10	10
24/11/19	8	9	0
25/11/19	7	11	6
26/11/19	8	12	5
27/11/19	7	10	26
09/10/19	8	16	0

d. Trial design



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
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