CP 205 AHDB Horticulture Efficacy Trials 2022
Final Trial Report

Work package:	WP5
Title:	Cabbage stem flea beetle (*Psylliodes chrysocephala*) control on oriental cabbage
Crop	Pak Choi
Target	Cabbage stem flea beetle (*Psylliodes chrysocephala*)
Lead researcher:	Prof Rosemary Collier
Organisation:	University of Warwick
Period:	October – November 2022
Report date:	27 February 2023
Report authors:	Andrew Jukes and Prof Rosemary Collier
ORETO Number: (certificate should be attached)	381

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: 27 February 2023 Author's signature: Rosemary Collier

Trial Summary

Introduction

During the summer, adult cabbage stem flea beetles (CSFB) become inactive and move to cool shaded places before returning to feed on brassica plants in the autumn. After a few weeks, eggs are laid from which larvae emerge, these tunnel into the petioles of brassica plants throughout the winter and into spring depending on weather conditions. From late autumn the larvae migrate to the soil to pupate. The adults hatch from these pupae in summer. There is one generation per year.

Adult CSFB feeding shows up as distinct "shot" holes in leaves and is particularly a problem in seedlings and young plants. All brassicas can be affected but the plants most at risk are those grown in spring which are susceptible to the emerging adults and late summer/autumn which are susceptible to the adults returning to the crop to feed. The late summer/autumn crops are also susceptible to damage from the feeding larvae.

There has been quite a lot of recent work on management of CSFB in oil seed rape (OSR) and there is information on both synthetic insecticides (PhD by Caitlin Willis (Royal Agricultural University and Rothamsted Research) and PhD work by Claire Hoaru at Harper Adams). Several effective synthetic insecticides against adults and larvae were found but only some of these are approved or likely to be suitable for use in the UK on oriental cabbage. In terms of biopesticides then in lab trials, nematodes (especially *Heterorhabditis* species), *Beauveria bassiana* and FLiPPER (fatty acids) showed promise.

Of the products previously evaluated at Warwick Crop Centre for flea beetles (*Phyllotreta* species) in SP 59 in SCEPTREplus, Tracer (Spinosad) and Spruzit (Pyrethrins) were as effective as the standard Hallmark Zeon (Lambda cyhalothrin). There is no insecticide resistance recorded at Warwick Crop Centre in these species but none of the treatments appeared to have significant residual effects. Moreover, neither Tracer nor Spruzit are currently authorised for use on protected Pak Choi, where CSFB can be a severe problem.

In the case of oriental cabbage, adults are likely to be the main target and rapid knockdown is important to minimise leaf damage (and subsequent crop rejection), which would exclude, for example, nematodes and *Beauveria bassiana*.

The objective of this study was to evaluate synthetic and biological plant protection products for efficacy against cabbage stem flea beetle (*Psylliodes chrysocephala*) and crop safety on Pak Choi planted outdoors.

Methods

One trial was conducted. The original plan was to conduct the trial in polytunnnels inoculated with CSFB collected from commercial plant nurseries but, despite considerable effort, insufficient numbers of CSFB were found. The trial was therefore transferred to the open field and subjected to the natural autumn migration of CSFB. Pak Choi was raised in 308 Hassy trays and transplanted on 11 October. Treatments were applied as sprays when the first signs of damage were observed on 17 October and again one week later. Leaf damage was assessed by counting holes in 20 plants per plot one and two weeks after the first spray and damage due to larvae was assessed on 28 November (5 weeks after the second spray).

Results

The data was analysed using ANOVA. Treatments were not significantly different ($p<0.05$) on the first assessment but on the second assessment, all treatments except AHDB 9768 significantly reduced the number of CSFB feeding holes compared with the untreated control. Hallmark Zeon was the most effective treatment, leaving significantly less holes than all treatments except AHDB 9721. The results are presented in Table A and Figure A.

Table A Mean number of CSFB feeding holes per leaf in Pak Choi 24 and 31 October at Warwick Crop Centre in 2022. Treatments that were significantly different from the untreated control are highlighted in blue.

	Number of holes per leaf	
Treatment	24 Oct	31 Oct
Untreated	5.1	8.9
Hallmark[1]	2.6	4.1
AHDB 9768	5.0	7.9
AHDB 9721	3.0	5.0
AHDB 9723	4.5	7.0
AHDB 9965	4.2	7.0
Tracer[2]	3.6	6.2
AHDB 9837	3.8	6.2
F-value	2.154	10.799
P-value	0.076	<0.001
SED	0.880	0.659
5% LSD	1.815	1.361
df	24	24

[1] Hallmark Zeon has an off-label authorisation for use on protected but not outdoor Pak Choi. It was used outdoors in this trial under experimental permit followed by crop destruct

[2] Tracer has oriental cabbage EAMUs when used as an outdoor ground spray or as a drench during propagation (before transplanting), only.

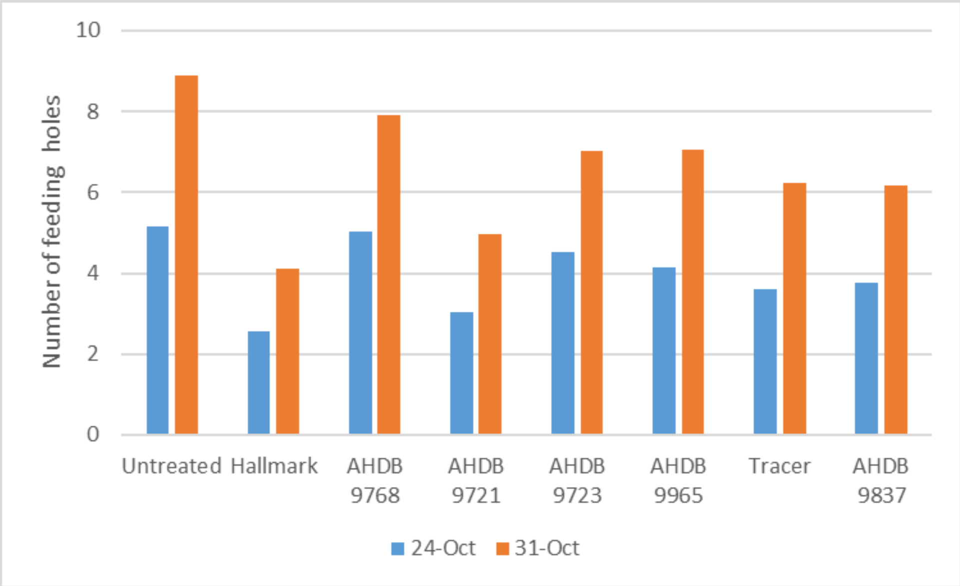

Figure A Mean number of CSFB feeding holes/leaf in a Pak Choi trial at Warwick Crop Centre, 1 and 2 weeks after treatment.

Take home message:

In Pak Choi, instant knockdown of CSFB adults is required to reduce the numbers of feeding holes. Hallmark Zeon proved to be the most effective product (authorised off-label for use on protected but not outdoor Pak Choi) and AHDB 9721 was similarly effective. AHDB 9723, AHDB 9965, Tracer and AHDB 9837 also provided significant reductions in damage but were less effective than Hallmark Zeon. Tracer is currently authorised off-label on oriental cabbage for outdoor foliar use and propagation drench only.

All of the products tested showed signs of reducing damage due to CSFB larvae, although none were significantly different from the untreated control.

CSFB is often reported to be resistant to pyrethroids but it appears that this is not the case with the local population at Warwick Crop Centre, Wellesbourne.

SCIENCE SECTION

Objectives

To evaluate synthetic and biological plant protection products for efficacy against cabbage stem flea beetle ((*Psylliodes chrysocephala*) and crop safety on Pak Choi planted outdoors.

Methods

Trial conduct

[*UK regulatory guidelines were followed, but EPPO guidelines took precedence. The following EPPO guidelines were followed:]*

Relevant EPPO guideline(s)		**Variation from EPPO**
PP 1/135	Phytotoxicity assessment	
PP 1/152	Design and analysis of efficacy evaluation trials	
PP 1/223	Introduction to the efficacy evaluation of plant protection products	

Test site

Item	**Details**
Location address	Warwick Crop Centre, Wellesbourne Campus, University of Warwick, Wellesbourne, Warwick, CV35 9EF. Latitude 52 12 18 N Longitude 1 36 00 W
Crop	Pak Choi
Cultivar	Chifu F1
Soil or substrate type	Sandy-loam soil P:K:Mg 4:3:2 pH 6.5
Agronomic practice	See appendix
Prior history of site	2021 - carrots

Trial design

Item	**Details**
Trial design:	(4x4)/2 Trojan Square
Number of replicates:	4
Row spacing:	35 cm
Plot size: (w x l)	1.83 x 4 m
Plot size: (m^2)	7.3
Number of plants per plot:	68
Leaf Wall Area calculations	n/a

Treatment details

AHDB Code	Active substance	Product name/ manufacturer code	Formulation batch number	Content of active substance in product	Formulation type	Adjuvant
	Untreated					
Hallmark Zeon [1]	Lambda cyhalothrin	Hallmark Zeon	BSW00F0670	100 g/l	CS	None
AHDB 9768	*N/D*	*N/D*	*N/D*	*N/D*	-	None
AHDB 9721	*N/D*	*N/D*	*N/D*	*N/D*	EW	None
AHDB 9723	*N/D*	*N/D*	*N/D*	*N/D*	SC	None
AHDB 9965	*N/D*	*N/D*	*N/D*	*N/D*	SG	None
Tracer [2]	Spinosad	Tracer	F056J72126	480 g/l	SC	None
AHDB 9837	*N/D*	*N/D*	*N/D*	*N/D*	WG	None

[1] Hallmark Zeon has an off-label authorisation for use on protected but not outdoor Pak Choi. It was used outdoors in this trial under experimental permit followed by crop destruct

[2] Tracer has oriental cabbage EAMUs when used as an outdoor ground spray or as a drench during propagation (before transplanting), only.

Application schedule

Treatment number	Treatment: product name or AHDB code	Rate of active substance (ml or g a.s./ha)	Rate of product (l or kg/ha)	Application code
2	Hallmark Zeon	10 g	0.1 l	A C
3	AHDB 9768	*N/D*	*N/D*	B D
4	AHDB 9721	*N/D*	*N/D*	B D
5	AHDB 9723	*N/D*	*N/D*	A C
6	AHDB 9965	*N/D*	*N/D*	A C
7	Tracer	96 g	0.2 l	A C
8	AHDB 9837	*N/D*	*N/D*	A C

Application details

	Application A	Application B	Application C	Application D
Application date	17/10/22	17/10/22	24/10/22	24/10/22
Time of day	17.00	17.00	15.00	15.00
Crop growth stage (Max, min average BBCH)	13	13	14	14
Crop height (cm)	3	3	4	4
Crop coverage (%)	2	2	3	3
Application Method	Spray			
Application Placement	Foliage			
Application equipment	Berthoud Vermorel 2000HP			
Nozzle pressure	2 bar			

Nozzle type	HC02			
Nozzle size	02			
Application water volume/ha	200	400	200	400
Temperature of air - shade (°C)	12	12	12	12
Relative humidity (%)	92	92	85	85
Wind speed range (m/s)	Not recorded			
Dew presence (Y/N)	n/a			
Temperature of soil - 2-5 cm (°C)	Not recorded			
Wetness of soil - 2-5 cm	Damp	Damp	Wet	Wet
Cloud cover (%)	Not recorded			

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

Common name	Scientific Name	EPPO Code	Infestation level pre-application	Infestation level at start of assessment period	Infestation level at end of assessment period
Cabbage stem flea beetle	*Psylliodes chrysocephala*	PSYICH	Not known		

Method details

Cabbage stem flea beetle (CSFB) numbers were monitored as part of routine insect catches in a set of three yellow water traps which were positioned in an adjacent plot of swede at Warwick Crop Centre.

Pak Choi (cv Chifu F1) was sown in 308 Hassy trays on 22 September and propagated in a glasshouse. Prior to transplanting, on 23 September and 7 October, the field trial area was cultivated with a bed-former. The Pak Choi was transplanted outdoors into 4m plots (8 beds, 4 plots/bed) with 25 cm spacing along rows and 4 rows per bed on 11 October.

Treatments were applied on 17 and 24 October using a knapsack sprayer fitted with a 3 x HC02 nozzles, operating at a pressure of 2 bar for a fine/medium droplet quality. Water volume was 200 l/ha for all conventional plant protection products and 400 l/ha for biological plant protection products.

The number of leaves and the number of CSFB adult feeding holes per plant was counted on 20 plants from the middle two rows in each plot on 24 and 31 October. Twenty plants from the middle two rows per plot were removed from the field on 28 November, washed and assessed for feeding damage due to CSFB larvae by cutting through the plant longitudinally. Plants were recorded as having no damage, external damage only (light damage) or internal damage (heavy damage). Numbers of larvae were also counted where they could be found.

Assessment details

	Evaluation Timing (DA)*				
Evaluation date	**After first conventional insecticides**	**After first bio-pesticides**	**Crop Growth Stage (BBCH)**	**Evaluation type (efficacy, phytotoxicity)**	**Assessment**
24/10/22	7	7	015	Efficacy	Feeding holes
24/10/22	7	7	015	Phytotoxicity	Leaf damage
31/10/22	14	14	016	Efficacy	Feeding holes
28/11/22	42	42	018	Efficacy	Larval feeding

[*] DA – days after application

Statistical analysis

This trial was designed as a Trojan square for 8 treatments in a (4*4)/2 design. The number of holes per plant due to adult CSFB (2 assessments) and the number of plants with no, or no plus light, damage due to CSFB larvae were analysed by ANOVA using the Excel data package. The analyses were interpreted using treatment means together with standard errors for the differences (SED) between means and associated 5% least significant differences (LSD). In all cases plot totals were used.

Results

There was no evidence of phytotoxicity with any treatment.

The number of CSFB caught in yellow water traps in an adjacent plot of swede is presented in Figure 1.

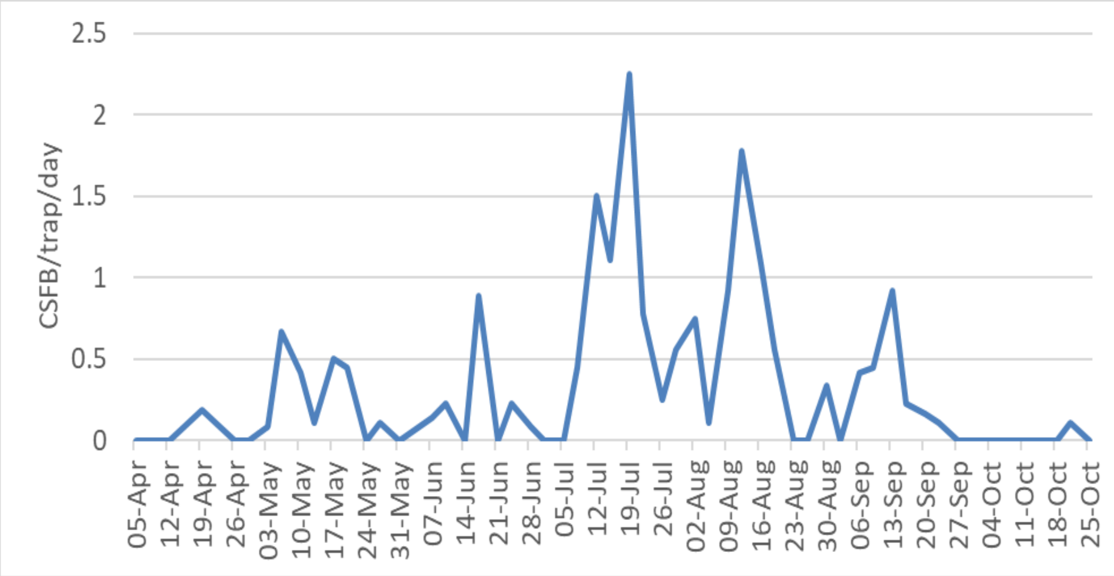

Figure 1 The mean number of CSFB per trap per day caught in yellow water traps at Warwick Crop Centre, Wellesbourne between 5 April and 25 October 2022

High levels of damage from CSFB adults on Pak Choi were recorded on 24 October, 1 week after the first spray treatments. One week after the second spray, on 31 October, the levels of damaged had increased. The difference between treatments in the mean number of holes per leaf was not quite significant ($p = 0.076$) on 24 October but was significant ($p < 0.001$) on 31 October. All treatments except AHDB 9768 significantly reduced damage compared with the untreated control. Hallmark Zeon was the most effective treatment, resulting in significantly less damage than all treatments except AHDB 9721. The results are presented in Table 1 and Figure 2.

There was also considerable damage due to CSFB larvae feeding in plants sampled on 28 November, 5 weeks after second treatment application. Although the analyses were not significant at the 5% level ($p = 0.084$ for numbers of plants with no damage), pair-wise comparisons using the LSD would suggest that Hallmark Zeon, AHDB 9768, AHDB 9723 and AHDB 9837 all reduced damaged compared with the untreated control. However, differences between these “effective” treatments and the other treatments are small. The results are presented in Table 2 and Figure 3.

Table 1 Mean number of CSFB feeding holes per leaf in Pak Choi 24 and 31 October at Warwick Crop Centre in 2022. Treatments that were significantly different from the untreated control are highlighted in blue.

	Mean number of holes per leaf (20 plants per plot and 4 plots per treatment)	
Treatment	24 Oct	31 Oct
Untreated	5.1	8.9
Hallmark	2.6	4.1
AHDB 9768	5.0	7.9

AHDB 9721	3.0	5.0
AHDB 9723	4.5	7.0
AHDB 9965	4.2	7.0
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F-value	2.154	10.799
P-value	0.076	<0.001
SED	0.880	0.659
5% LSD	1.815	1.361
Df	24	24

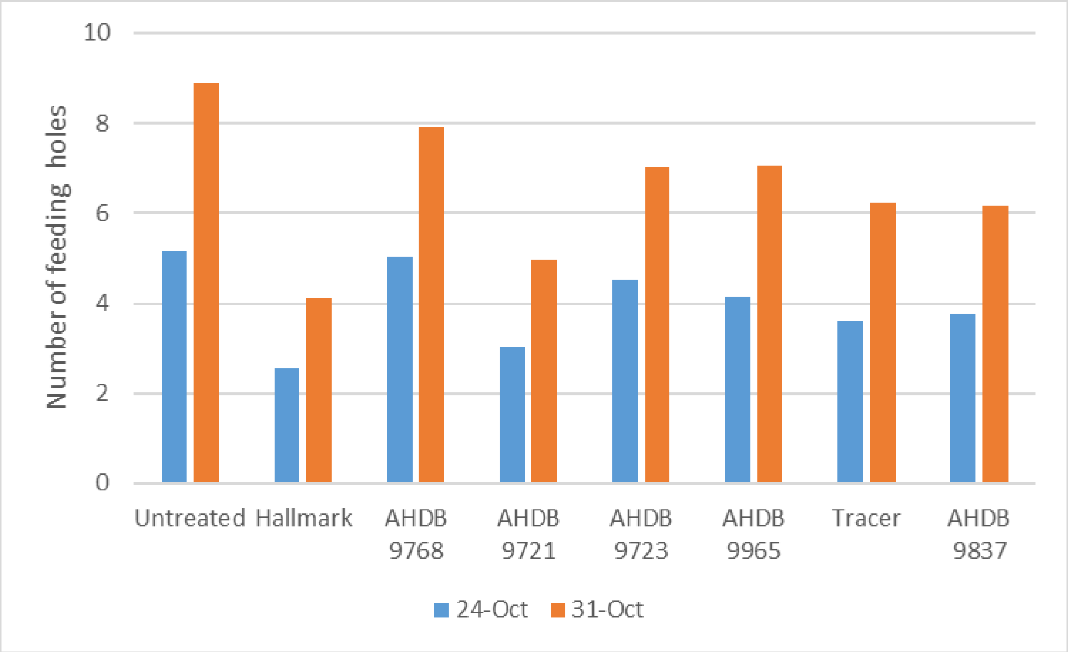

Figure 2 Mean number of CSFB feeding holes per leaf in Pak Choi on 24 and 31 October at Warwick Crop Centre in 2022, 1 and 2 weeks after first treatment

Table 2 Mean number of plants per plot with CSFB larvae damage and number of larvae recovered in Pak Choi on 28 November at Warwick Crop Centre in 2022.

Treatment	No damage	No or light damage	Heavy damage	Larvae/plant
Untreated	9	12.5	7.5	0.25
Hallmark	18.25	19.75	0.25	0
AHDB 9768	16.25	18	2.25	0
AHDB 9721	14.5	17	3	0.25
AHDB 9723	17.75	19.5	0.5	0
AHDB 9965	14.5	15.5	4.5	0.25
Tracer	14	15.75	4.25	0.75

AHDB 9837	18	18.75	1.25	0.25
F-value	2.090	1.810	1.788	
P-value	0.084	0.132	0.136	
SED	2.994	2.571	2.574	
5% LSD	6.179	5.306	5.312	
df	24	24	24	

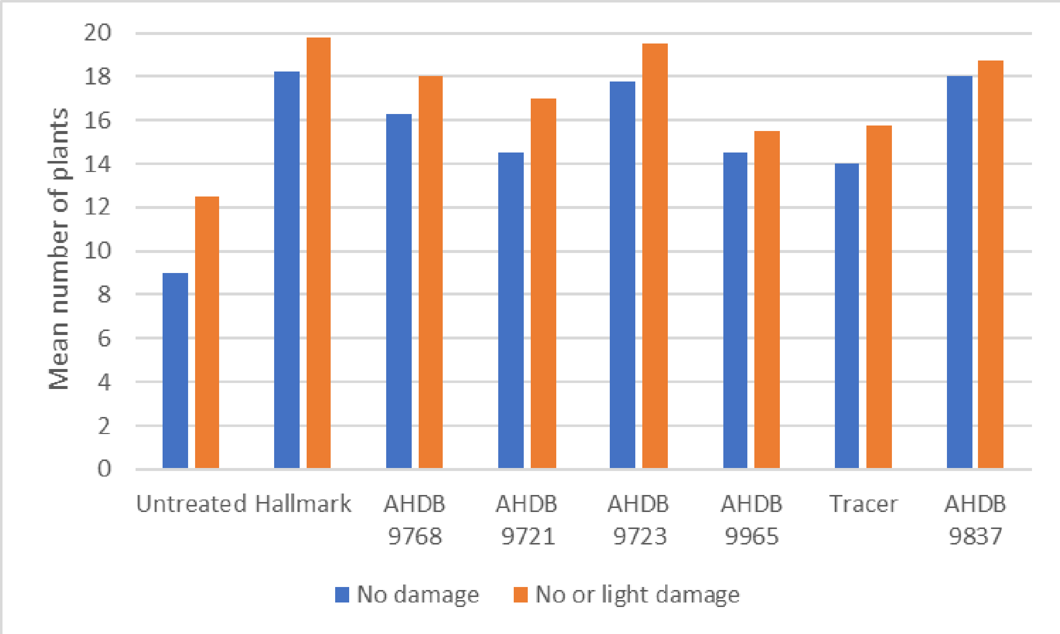

Figure 3 Mean number of Pak Choi plants with no damage, or no damage plus light damage, due to CSFB larvae on 28 November at Warwick Crop Centre in 2022.

Discussion

Instant knockdown of CSFB adults is required to minimise the numbers of feeding holes on Pak Choi leaves, which can lead to crop rejection. Of the products tested, feeding damage was limited most effectively through use of Hallmark Zeon, closely followed by AHDB 9721. The only product that did not significantly reduce leaf feeding damage was AHDB 9768.. All of the other products tested (AHDB 9723, AHDB 9965, Tracer and AHDB 9837) provided significant reductions in damage but were less effective than Hallmark Zeon.

Reductions in numbers of CFSB larvae found in Pak Choi plants 5 weeks after second spray application could have been a result of control of adults (and therefore a reduction in egg laying), control of larvae, or both. Although a considerable number of plants were damaged by CSFB larvae and there were clear differences between some treatments and the untreated control the analyses were not significant at the 5% level. Interestingly, the next most effective product after Hallmark Zeon (best control of adults) appears to be AHDB 9768 which was largely ineffective in controlling CSFB adults. It is possible that this biological product, while less useful for rapid adult 'knock down', could reduce CSFB larval numbers and could potentially contribute to pest management where sequential cropping is done under protection.

CSFB is often reported to be resistant to pyrethroids but it appears that this is not the case with the local population at Warwick Crop Centre.

The date profile of the number of CSFB caught in yellow water traps in a nearby, established swede crop could suggest a migration of CSFB away from the field in July with a return in August and mid-September, but might also indicate that a proportion, at least, of CSFB remain active within crop fields through the summer. Interestingly no CSFB were caught in the traps between planting of the Pak Choi on 11 October and 21 October (when a single CSFB was caught). No further CSFB were caught during the course of the trial but they were observed within the trial and clearly did considerable damage both as adults and larvae. This may be an indication that the positioning of the water traps within an established swede crop was not ideal for monitoring CSFB, with them preferring young plants.

Conclusions

All the treatments tested provided some control of either CSFB adults, CSFB larvae or both, but the standard pyrethroid insecticide Hallmark Zeon was the most effective overall (authorised off-label for use on protected but not outdoor Pak Choi). However, where CSFB populations are resistant to pyrethroids, AHDB 9721, AHDB 9723, AHDB 9965, Tracer (with oriental cabbage EAMUs for outdoor foliar use and propagation drench only), and AHDB 9837 could contribute towards control of CSFB adults if applied in a timely manner. AHDB 9768 did not reduce feeding damage due to adult CSFB so would not reduce crop rejection but there is evidence that it could reduce damage due to CSFB larvae and therefore contribute to long term local population reduction. However, this would also be achieved by an effective "knock-down" insecticide.

Acknowledgements

We are very grateful to the AHDB for funding these trials and to Kim Parker in particular for all her support for them. We are also grateful to Peter Waldock of HL Hutchinsons Ltd for advice and would also like to thank the crop protection companies for the supply of products for testing and CN Seeds for providing the Pak Choi seed.

References

There is a presentation relating to this work on the University of Warwick web site:
Flea beetles (warwick.ac.uk)

Appendix

a. Trial diary

Date	Notes
22/09/2022	10 x 308 Hassy trays sown with Pak Choi
22/09/2022	Springtined area
23/09/2022	Bed-formed
07/10/2022	Bed-formed lightly
10/10/2022	Marked out 4 rows per bed @ 35 cm with 25 cm up
10/10/2022	Sprayed off with glyphosate
11/10/2022	Planted Pak Choi
11/10/2022	Set up bird netting
17/10/2022	Spray treatments applied
24/10/2022	Spray treatments applied

b. Trial Photographs

Adult CSFB on Pak Choi

CSFB adult feeding damage on Pak Choi

CSFB larvae damage in Pak Choi petioles

CSFB larvae mining into Pak Choi stem

CSFB larvae in base of Pak Choi stem

c. Raw data

Numbers of holes per leaf on two dates (plot means)

Treatment	Plot	24-Oct	31-Oct
1	4	5.93	8.6
1	10	6.57	8.4
1	24	5.36	10.3
1	30	2.72	8.2
2	2	3.48	3.4
2	12	2.73	4.3
2	22	3.33	5.0
2	31	0.75	3.7
3	7	4.57	7.3
3	14	5.84	8.0
3	19	4.42	8.3
3	26	5.23	8.0
4	6	3.18	5.4
4	15	3.36	4.5
4	17	3.35	5.5
4	27	2.27	4.5
5	8	3.68	5.4
5	11	6.48	7.2
5	18	5.05	9.5
5	29	2.93	6.1
6	5	4.14	5.6
6	9	6.23	7.6
6	20	4.03	7.5
6	32	2.20	7.5
7	3	4.91	6.5
7	16	2.71	5.4
7	21	3.39	6.1
7	25	3.37	6.9
8	1	4.64	7.1
8	13	4.65	6.4
8	23	3.42	5.7
8	28	2.33	5.4

Number of plants with CSFB larvae damage

		Number of plants			
Treatment	Plot	No damage	Surface damage	Internal mining	Larvae
1	4	6	3	11	0
1	10	5	5	10	1
1	24	13	1	6	0
1	30	12	3	5	0

2	2	19	0	1	0
2	12	19	1	0	0
2	22	19	1	0	0
2	31	16	4	0	0
3	7	16	1	3	0
3	14	18	1	1	0
3	19	17	1	3	0
3	26	14	4	2	0
4	6	15	4	1	0
4	15	20	0	0	0
4	17	6	4	10	1
4	27	17	2	1	0
5	8	19	1	0	0
5	11	18	1	1	0
5	18	16	3	1	0
5	29	18	2	0	0
6	5	19	1	0	0
6	9	5	2	13	0
6	20	16	0	4	0
6	32	18	1	1	1
7	3	6	2	12	3
7	16	19	1	0	0
7	21	19	1	0	0
7	25	12	3	5	0
8	1	18	1	1	0
8	13	16	1	3	0
8	23	20	0	0	0
8	28	18	1	1	1

Weather data (recorded at Warwick Crop Centre)

	Temperature (^{0}C)		
DATE	09-09 MAX	09-09 MIN	09-09 Rainfall
01/10/2022	18.3	9.8	0
02/10/2022	17.9	10.3	0
03/10/2022	18.1	4.5	0
04/10/2022	19.2	10.2	0
05/10/2022	19.2	15	1.4
06/10/2022	18.4	8.2	0.2
07/10/2022	18.7	11.4	5.6
08/10/2022	16.3	5.3	0
09/10/2022	18	3.7	4.2

10/10/2022	16.1	7.8	0
11/10/2022	15	0.9	0
12/10/2022	16	3	0.2
13/10/2022	16.3	10.3	0.2
14/10/2022	17.3	7.6	1.8
15/10/2022	15.7	9.5	1.2
16/10/2022	17	7	6.2
17/10/2022	17.7	11.9	0
18/10/2022	16.9	2.3	0
19/10/2022	16.4	8.5	1
20/10/2022	15.8	11.7	3
21/10/2022	16.1	9.3	13.2
22/10/2022	17.2	11.9	14.2
23/10/2022	18.6	12.9	11.4
24/10/2022	15.8	11	0.2
25/10/2022	17.2	10.2	1.4
26/10/2022	18.9	11.7	2.6
27/10/2022	18.9	11.4	0.8
28/10/2022	17.2	14.4	3.6
29/10/2022	21	11.7	0
30/10/2022	17	12.6	3
31/10/2022	16.5	11.4	11.8
01/11/2022	14.4	10.8	3.4
02/11/2022	14.2	6.6	10
03/11/2022	12.9	9.3	0.4
04/11/2022	12.9	2.8	0.4
05/11/2022	13.5	4.9	0.6
06/11/2022	13.1	4.5	5
07/11/2022	15	9	6.2
08/11/2022	14.3	10	0.4
09/11/2022	13.8	9.5	0
10/11/2022	15.5	10.3	0
11/11/2022	15.9	12.8	0
12/11/2022	16.4	8.2	0
13/11/2022	14.7	9.3	0
14/11/2022	13.4	8.8	4.6
15/11/2022	12.9	8.5	5.6
16/11/2022	11.7	6.7	11.8
17/11/2022	10.8	7.7	0.2
18/11/2022	11.8	7.1	0
19/11/2022	11.1	4.6	2.4
20/11/2022	10.5	3.2	0.2
21/11/2022	8.1	2.3	10.4
22/11/2022	9.6	4.8	4

23/11/2022	11.3	1.4	4
24/11/2022	12.5	5.7	4.8
25/11/2022	11.6	6.1	0
26/11/2022	12.5	7.1	3.6
27/11/2022	11.7	8.8	0.2
28/11/2022	9	5.3	0.2
29/11/2022	5.7	2.7	0
30/11/2022	7.5	3.8	0.2

d. Trial design

8	2	7	1	6	4	3	5
1	2	3	4	5	6	7	8
6	1	5	2	8	3	4	7
9	10	11	12	13	14	15	16
4	5	3	6	7	2	8	1
17	18	19	20	21	22	23	24
7	3	4	8	5	1	2	6
25	26	27	28	29	30	31	32