SCEPTREPLUS

Final Trial Report

Trial code:	SP15 Yr2
Title:	Efficacy of plant protection products against western flower thrips (WFT) on protected ornamentals
Crop	Verbena Protected ornamentals (verbena), trial data also applicable to other flowering protected ornamentals and flowering protected hardy nursery stock
Target	Western flower thrips – *Frankliniella occidentalis* - FRANOC
Lead researcher:	Jude Bennison
Organisation:	ADAS
Period:	May to October 2018
Report date:	2018
Report author:	Jude Bennison
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

22/2/19……
Date

JABennison

Grower Summary

Introduction

Western flower thrips (*Frankliniella occidentalis*) causes feeding damage to flowers and leaves that can make plants unmarketable. The pest is widely resistant to many chemical plant protection products. Biological control methods are widely used within Integrated Pest Management (IPM) programmes but sometimes these need supplementing with a compatible plant protection product; therefore new effective actives need development.

Methods

Verbena (cv Quartz) plants were grown in thrips-proof cages in two glasshouse compartments at ADAS Boxworth between May and August 2018. Once the plants were flowering 30 WFT adults were released into each cage. The first treatments were applied four days after WFT release when flower damage was first seen. There were six replicate cages (plots) for each of eight treatments. Six treatments (four biopesticides and two conventional insecticides) were tested compared with a water control treatment and the standard treatment thiamethoxam (Actara). All foliar treatments were applied using a knapsack sprayer in 600 L/ha water. Treatments were applied over a 24-day period at time intervals recommended by each manufacturer. These varied from twice at 7-day intervals to four times at 7-day intervals and eight times at 4-day intervals. Assessment of percentage flower and leaf damage and numbers of WFT adults and larvae per flower and leaves were made one day before the first application and three, six, 14, 21 and 28 days after the first application.

Results and Conclusions

- The botanical biopesticide Azatin applied four times at 7-day intervals was as effective as the standard positive control (conventional insecticide) Actara applied twice at 7-day intervals in reducing mean numbers WFT adults, larvae and percentage flower and leaf area damaged compared with the water controls on all assessment dates.
- The conventional insecticide AHDB 9933, applied in a tank mix with the sugars product Attracker, applied twice at 7-day intervals was as effective as Azatin at all assessments except for 28 days after first treatments when it was less effective in reducing percentage flower damage.
- The conventional insecticide AHDB 9951 applied in a tank mix with Attracker four times at 7-day intervals was also as effective as Azatin at all assessments except for 28 days after first treatments when it was less effective in reducing percentage flower damage.
- The biopesticide AHDB 9970 (Flipper) and the botanical biopesticide AHDB 9964, both applied four times at 7-day intervals were equally effective on all assessment dates. Both treatments were as effective as the above most effective three treatments until WFT numbers increased 21 and 28 days after first treatments, when control was less reliable.
- The botanical biopesticide Majestik, applied seven times at 4-day intervals gave similar control as the other treatments until WFT numbers increased 28 days after first treatments when it was the least effective treatment.
- No treatments caused phytotoxic effects.

Take-home message: Azatin is effective against WFT and is approved for use against WFT on protected ornamentals. Two coded insecticides, both used as a tank mix with Attracker were also effective and will be useful for WFT control when they are approved for use on protected ornamentals in the UK. Flipper, a coded biopesticide and Majestik gave effective control against low numbers of WFT but were less effective when numbers increased.

Science Section

Objectives

1. To evaluate the effectiveness of conventional insecticides and biopesticides against western flower thrips on protected ornamentals as measured by numbers of live adults and larvae per flower and leaves and percentage damaged flower and leaf area.
2. To monitor the treated crop for phytotoxicity

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 1/152(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 1/160(2)	Thrips on glasshouse crops	Size of cages and flowering stage of plants limited the number of plants per plot to 4 rather than a minimum of 15. Six replicates of each treatment used rather than the minimum of four.

Deviations from EPPO guidance: as in table above.

Test site

Item	**Details**
Location address	ADAS Boxworth, Boxworth, Cambridge, CB23 4NN
Crop	Verbena
Cultivar	Quartz
Soil or substrate type	M2 growing media
Agronomic practice	See Appendix
Prior history of site	Glasshouse compartments used for evaluating control methods for pests and diseases on various crops

Trial design

Item	**Details**
Trial design:	Randomised blocks in two glasshouse compartments
Number of replicates:	6
Row spacing:	1L pots arranged in two rows of two
Plot size: (w x l)	0.5x0.5x0.5m thrips-proof cage
Plot size: (m^2)	0.125 m^2
Number of plants per plot:	Four
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	Formulation type
-	Water (-ve control)	-	-	-	-
-	Thiamethoxam (+ve control)	Actara	KW16A007	250 g/kg	WG
AHDB 9933	N/A	N/A	N/A	N/A	N/A
AHDB 9970	N/A	N/A	N/A	N/A	N/A
-	Azadirachtin	Azatin	E162441	26 g/L	EC
-	Maltodextrin	Majestik	10567	598 g/L	SL
AHDB 9964	N/A	N/A	N/A	N/A	N/A
AHDB 9951	N/A	N/A	N/A	N/A	N/A

The sugar product Attracker was used in a tank mix as recommended by the manufacturers of these two products.

Rain water was used as recommended by the manufacturer.

Application rates and schedule

Treatment number	Treatment: product name or AHDB code	Rate of active substance in product	Rate of product/ha when used at 600L/ha	Application code
1	Water	-	-	A,C,F,I
2	Actara	250 g/kg	0.4 kg/ha (EAMU 0186/2014)	A,C
3	AHDB 9933plus Attracker	N/A	10g/ 100L (600g/ha plus 750 mlha)	A,C
4	Flipper	479.8g/L	1L/100L (6L/ha)	A,C,F,I
5	Azatin	26g/L	140 ml/100L (840 ml/ha)	A,C,F,I
6	Majestik	598g/L	25ml/L (15L/ha)	A,B,D,E,G,H,I ,J
7	AHDB 9964	N/A	650ml/100L (3.9L/ha)	A,C,F,I
8	AHDB9951 plus Attracker	N/A	0.75L/ha plus 2 ml/L (1.2L/ha)	A,C,F,I

Application details

Application number	A	B	C	D	E	F	G	H	I	J
Application date	06/07/2018	10/07/2018	13/07/2018	14/07/2018	18/07/2018	20/07/2018	22/07/2018	26/07/2018	27/07/2018	30/07/2018
Treatments	1-8	6	1,2,3,4,5,7,8	6	6	1,4,5,7,8	6	6	1,4,5,7,8	6
Time of day	06.50	09.05	06.45	08.15	07.18	07.20	09.20	06.40	06.40	07.35
Crop growth stage (Max, min average BBCH)	flower bud to open flower	flower bud to open flower	flower bud to open flower	flower bud to open flower	flower bud to open flower	flower bud to open flower	flower bud to open flower	flower bud to open flower	flower bud to open flower	flower bud to open flower
Application Method	spray	spray	spray	spray	spray	spray	spray	spray	spray	spray
Application Placement	foliar	foliar	foliar	foliar	foliar	foliar	foliar	foliar	foliar	foliar
Application equipment	Oxford Precision sprayer (knapsack)	Oxford Precision sprayer (knapsack)	Oxford Precision sprayer (knapsack)	Oxford Precision sprayer (knapsack)	Oxford Precision sprayer (knapsack)	Oxford Precision sprayer (knapsack)	Oxford Precision sprayer (knapsack)	Oxford Precision sprayer (knapsack)	Oxford Precision sprayer (knapsack)	Oxford Precision sprayer (knapsack)
Nozzle pressure	2.8 bar	2.8 bar	2.8 bar	2.8 bar	2.9 bar	2.8 bar	2.8 bar	3 bar	3 bar	3 bar
Nozzle type	Hollow cone	Hollow cone	Hollow cone	Hollow cone	Hollow cone	Hollow cone	Hollow cone	Hollow cone	Hollow cone	Hollow cone
Nozzle size	HC/1.74/3	HC/1.74/3	HC/1.74/3	HC/1.74/3	HC/1.74/3	HC/1.74/3	HC/1.74/3	HC/1.74/3	HC/1.74/3	HC/1.74/3
Application water volume/ha	600	600	600	600	600	600	600	600	600	600
Temperature of air - shade (°C)	21.2	23.7	20.1	27.0	21.4	24.1	29.2	22.0	23.5	21.7
Relative humidity (%)	73.8	55.4	76.4	54.5	64.0	59.7	44.6	76.8	74.4	77.4
Wind speed range (m/s)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dew presence (Y/N)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Temperature of soil - 2-5 cm (°C)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wetness of soil - 2-5 cm	Damp	Damp	Damp	Damp	Damp	Damp	Damp	Damp	Damp	Damp
Cloud cover (%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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	Infection level at end of assessment period
Western flower thrips	*Frankliniella occidentalis*	FRANOC	0.88[1]	0.38[1]	10.0[1]

[1] Mean numbers of adults per flower

Assessment details

Prior to the application of treatments, water-sensitive paper was used to demonstrate spray coverage, using water one day before the release of WFT. Papers were attached to the upper and lower sides of a top and lower leaf on a representative verbena plant using paper clips. Water was then applied to the plant at 600L/ha using the same equipment used for application of all other treatments in the trial. The papers were then assessed to confirm droplet deposition.

Thirty western flower thrips adults (27 females and three males) from the ADAS laboratory culture were added to each plot (thrips-proof cage) four days before first treatments were applied (treatments started when the first thrips damage to flowers was seen). Treatments were applied over a 24-day period at time intervals recommended by each manufacturer. These varied from twice at 7-day intervals, to four times at 7-day intervals and eight times at 4-day intervals.

Assessments of WFT numbers and damage were done one day before the first treatments were applied and three, six 14, 21 and 28 days after the first treatments.

On each assessment date numbers of flowers, live WFT adults and larvae on all the flowers and leaves in each cage, and percentage flower and leaf damage caused by WFT were recorded. Each flower head was tapped onto a white plastic tray and any thrips dropping to the tray were recorded, followed by tapping the thrips back onto the assessed flower. Leaf assessments were done by examining the upper and lower surfaces of each leaf. The assessments were done *in-situ* using a headband magnifier, to avoid removing flowers, leaves and thrips from the cages.

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)
5/7/2018	-1	flowering	Efficacy and phytotoxicity	Numbers of live WFT adults and larvae per flower and leaves, % flower and leaf damage.
9/7/2018	3	flowering	Efficacy and phytotoxicity	Numbers of live WFT adults and larvae per flower and leaves, % flower and leaf damage.
12/7/2018	6	flowering	Efficacy and phytotoxicity	Numbers of live WFT adults and larvae per flower and leaves, % flower and leaf damage.
20/7/2018	14	flowering	Efficacy and phytotoxicity	Numbers of live WFT adults and larvae per flower and leaves, % flower and leaf damage.
27/7/2018	21	flowering	Efficacy and phytotoxicity	Numbers of live WFT adults and larvae per flower and leaves, % flower and leaf

				damage.
3/8/2018	28	flowering	Efficacy and phytotoxicity	Numbers of live WFT adults and larvae per flower and leaves, % flower and leaf damage.

* DA – days after first application

Statistical analysis

The data were analysed using Analysis of Variance (ANOVA). Angular transformation was used for data recorded as percentage flower or leaf area damaged. Abbott's formula was used to calculate percentage reduction in numbers of WFT or percentage of flower or leaf area damaged compared with the control where there was a significant treatment effect.

Results

Spray coverage

Spray coverage was good on the upper side of the top and bottom leaves (Figure 4, Appendix 1) but very little or no spray reached the lower leaf side in both leaf positions. This result was consistent with that given in the SCEPTREplus WFT trial on verbena in 2017.

Numbers of WFT adults per flower

On the first assessment, completed the day before WFT were released to the cages, there was a mean of 0.88 WFT adults per flower (Table 1 and Figure 1a) in the water controls, which was higher than mean numbers of adults in other treatments but not significantly higher.

On the first and second post-treatment assessment dates three and six days after first treatments, no treatments significantly reduced mean numbers of WFT adults compared with the water controls. On the third post-treatment assessment date 14 days after first treatments, all treatments except for AHDB 9964 significantly reduced mean numbers of WFT adults per flower compared with the water controls and all effective treatments were equally effective. On the fourth post-treatment assessment date, 21 days after first treatments, all treatments significantly reduced mean numbers of WFT adults compared with the water controls and all treatments were equally effective. On the final assessment 28 days after first treatments, all treatments except for AHDB 9970, Majestik and AHDB 9964 significantly reduced numbers of WFT adults compared with the water controls and all effective treatments were equally effective.

Table 1. Mean numbers of live WFT adults per flower -1, 3, 6, 14, 21 and 28 days after the first treatment. **Significantly fewer than on the water control (P<0.05).** Values sharing the same letters are not significantly different, those with different letters are significantly different. N.S. = non-significant P value.

Date	5 July (-1 day)	9 July (Day 3)	12 July (Day 6)	20 July (Day 14)	27 July (Day 21)	3 Aug (Day 28)
Treatment						
Water -ve control	0.88	0.38	0.63	3.08 b	3.12 b	10.0 cd
Actara +ve control	0.21	0.13	0.04	**1.17 a**	**1.12 a**	**1.47 a**
AHDB 9933 + Attracker	0.33	0.33	0.21	**0.87 a**	**1.12 a**	**1.95 ab**
AHDB 9970	0.46	0.29	0.25	**0.96 a**	**1.42 a**	6.96 bcd
Azatin	0.25	0.21	0.08	**0.12 a**	**0.29 a**	**0.63 a**
Majestik	0.21	0.21	0.04	**1.0 a**	**0.38 a**	10.20 d
AHDB 9964	0.21	0.29	0.25	2.0 ab	**1.38 a**	4.88 abc
AHDB 9951 + Attracker	0.08	0.13	0.17	**0.71 a**	**0.63 a**	**3.14 ab**
F value	1.95	0.64	1.31	2.44	3.62	4.98
P value	0.091 (N.S.)	0.716 (N.S.)	0.276 (N.S.)	0.038	0.005	<0.001
d.f.	35	35	35	35	35	32
s.e.d.	0.250	0.164	0.234	0.823	0.667	2.398
l.s.d.	0.507	0.333	0.474	1.671	1.354	4.885

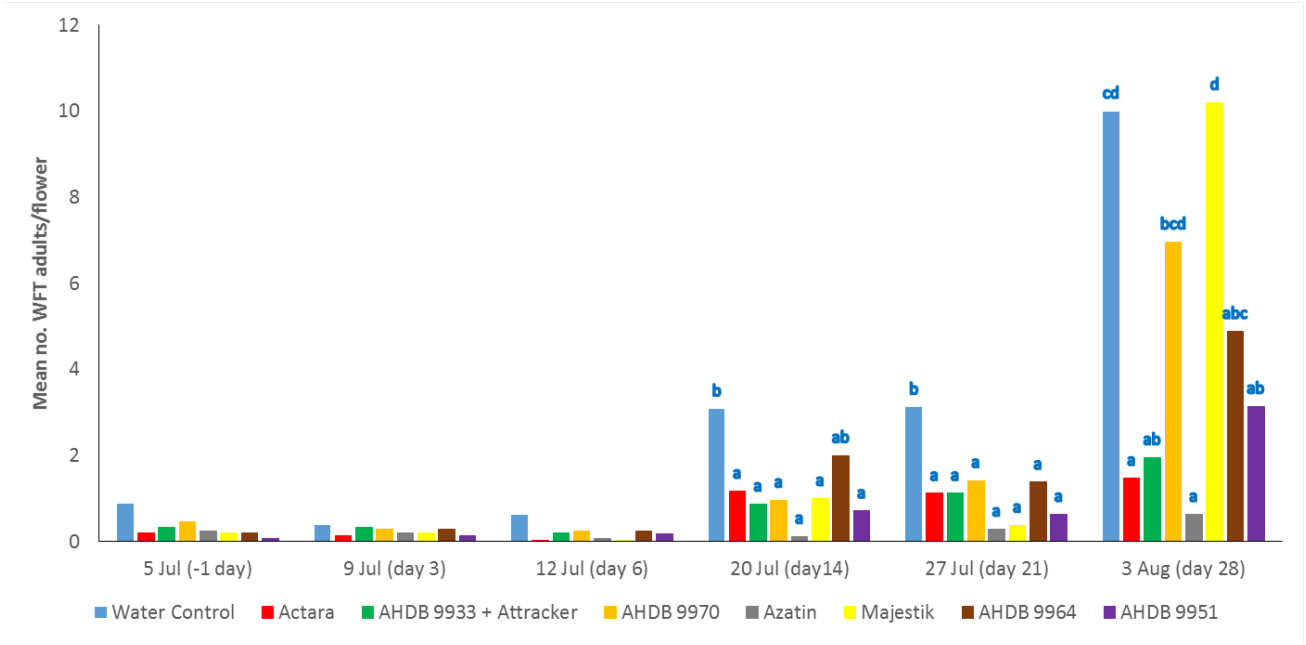

Figure 1a. Mean numbers of live WFT adults per flower -1, 3, 6, 14, 21 and 28 days after the first treatment. Values sharing the same letters are not significantly different, those with different letters are significantly different.

Numbers of WFT adults per flower without water controls

Numbers of WFT adults per flower were higher on the water control plants than in the other treatments the day before treatments were applied (-1 day). Although numbers were not significantly higher on this date than in other treatments, results were also analysed after removing the water control data as the higher numbers on -1 day may have affected numbers in the water controls on subsequent assessment dates compared with those in other treatments. This data is shown in Figure 1b. There were no significant differences in treatments until the final assessment 28 days after first treatments. On this date, Actara, AHDB 9933 in a tank mix with Attracker and Azatin were more effective than AHDB 9970 and Majestik but were equally effective as AHDB 9964 and AHDB 9951 in a tank mix with Attracker.

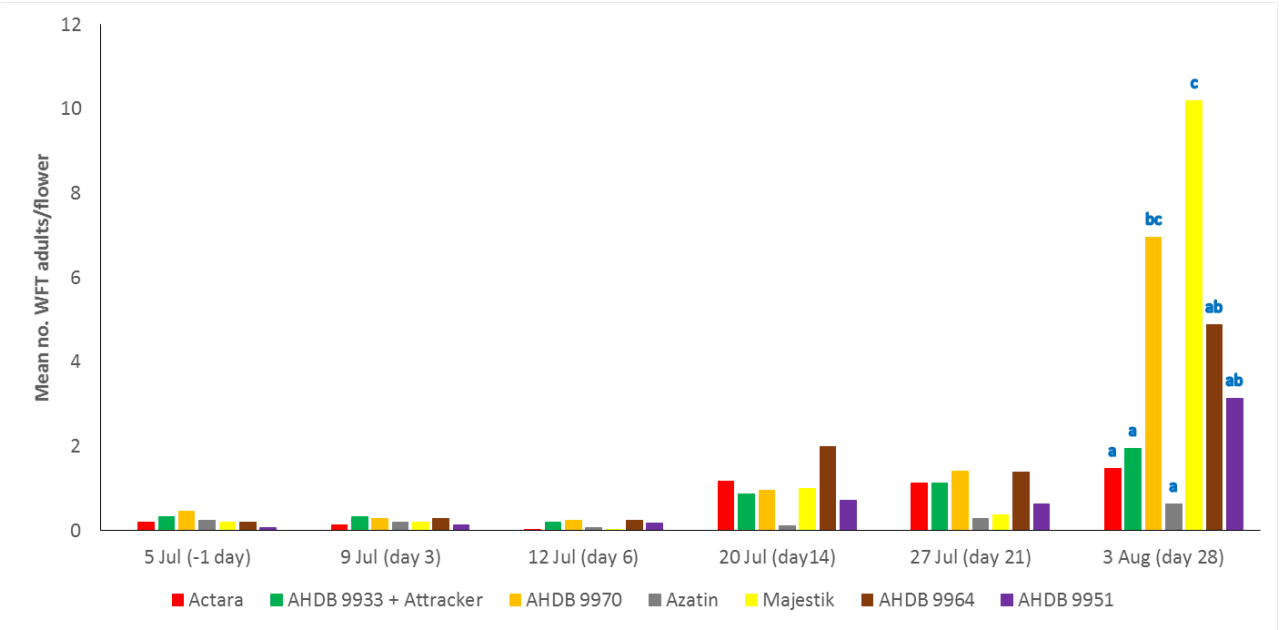

Figure 1b. Mean numbers of live WFT adults per flower -1, 3, 6, 14, 21 and 28 days after the first treatment. Water control data was removed from analysis. Values sharing the same letters are not significantly different, those with different letters are significantly different.

Abbott's formula was used to calculate percentage reduction in mean numbers of WFT adults per flower compared with the water controls and these are presented in Table 2.

Table 2. Percentage reduction in mean numbers of WFT adults per flower compared with Treatment 1 (water control) 3, 6, 14, 21 and 28 days after the first treatment (Abbott's formula). **Significantly fewer than on the water control (P<0.05).** No figure is given compared with T1 if there was no significant treatment effect on that date.

Date	9 July (Day 3)	12 July (Day 6)	20 July (Day 14)	27 July (Day 21)	3 Aug (Day 28)
Treatment					
Water control					
Actara +ve control			**62.15**	**64.0**	**78.57**
AHDB 9933 + Attracker			**71.62**	**64.0**	**67.67**
AHDB 9970			**68.93**	**54.66**	5.26
Azatin			**95.95**	**90.66**	**91.60**
Majestik			**67.56**	**88.0**	-53.84
AHDB 9964			35.13	**56.0**	31.87
AHDB 9951 + Attracker			**77.04**	**80.0**	**55.36**

Numbers of WFT larvae per flower

No WFT larvae were recorded in flowers or on leaves on the first assessment, completed the day before the first treatments were applied. There were no significant effects of treatment on numbers of larvae per flower three or six days after the first treatments were applied (Table 3 and Figure 2). All treatments significantly reduced mean numbers of larvae per flower compared with the water controls 14 and 21 days after the first treatments were applied and all treatments were equally effective. On the final assessment date, 28 days after the first treatment, all treatments except for AHDB 9970 and Majestik significantly reduced mean numbers of WFT larvae per flower compared with the water controls and all effective treatments were equally effective.

Table 3. Mean numbers of live WFT larvae per flower 3, 6, 14, 21 and 28 days after the first treatment. **Significantly fewer than on the water control (P<0.05).** Values sharing the same letters are not significantly different, those with different letters are significantly different. N.S. = not significant P value.

Date	9 July (Day 3)	12 July (Day 6)	20 July (Day 14)	27 July (Day 21)	3 Aug (Day 28)
Treatment					
Water -ve control	0.08	0.92	1.83 b	2.92 b	8.58 c
Actara +ve control	0.04	0.25	**0.17 a**	**0.92 a**	**3.53 ab**
AHDB 9933 + Attracker	0.04	0.54	**0.13 a**	**0.79 a**	**3.69 ab**
AHDB 9970	0.21	0.33	**0.5 a**	**1.38 a**	5.21 abc
Azatin	0.17	0.23	**0.08 a**	**0.12 a**	**0.63 a**
Majestik	0	0.25	**0.33 a**	**0.04 a**	7.31 bc
AHDB 9964	0	0.54	**0.75 a**	**1.29 a**	**3.79 ab**
AHDB 9951 + Attracker	0.13	0.42	**0.33 a**	**0.46 a**	**3.58 ab**
F value	0.76	1.39	3.32	4.40	2.97
P value	0.623 (N.S.)	0.240 (N.S.)	0.008	0.001	0.016
d.f.	35	35	35	35	32
s.e.d.	0.125	0.278	0.447	0.620	2.033
l.s.d.	0.254	0.564	0.908	1.260	4.141

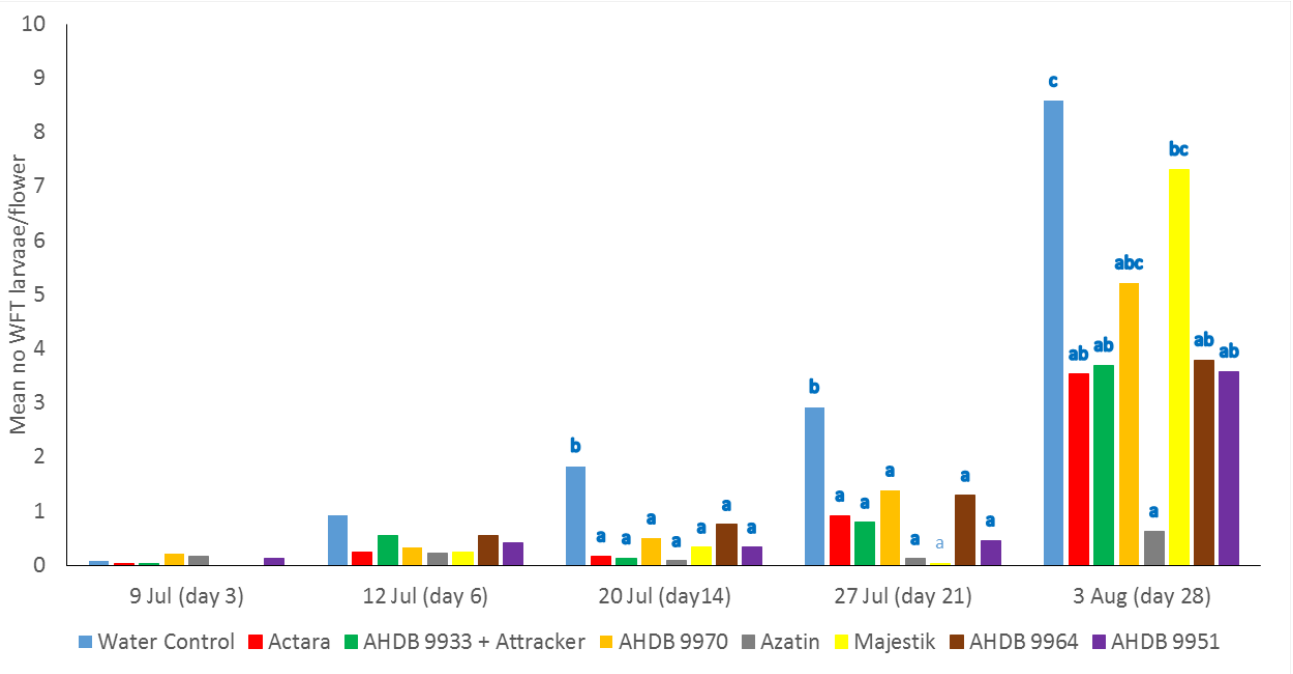

Figure 2. Mean numbers of live WFT larvae per flower 3, 6, 14, 21 and 28 days after the first treatment. Values sharing the same letters are not significantly different, those with different letters are significantly different.

Abbott's formula was used to calculate percentage reduction in mean numbers of WFT larvae per flower compared with the water controls and these are presented in Table 4.

Table 4. Percentage reduction in mean numbers of WFT larvae per flower compared with Treatment 1 (water control) 3, 6, 14, 21 and 28 days after the first treatment (Abbott's formula). **Significantly fewer than on the water control (P<0.05).** No figure is given compared with T1 if there was no significant treatment effect on that date.

Date	9 July (day 3)	12 July (day 6)	20 July (day 14)	27 July (day 21)	3 Aug (day 28)
Treatment					
Water control					
Actara +ve control			**90.91**	**68.57**	**58.06**
AHDB 9933 + Attracker			**93.18**	**72.86**	**53.14**
AHDB 9970			**72.73**	**52.86**	34.13
Azatin			**95.46**	**95.71**	**91.65**
Majestik			**81.82**	**98.57**	-10.17
AHDB 9964			**59.09**	**55.71**	**49.38**
AHDB 9951 + Attracker			**81.82**	**84.29**	**51.61**

Percentage of flower area damaged

Assessments of the mean percentage flower area damaged the day before treatments were applied and three, six, 14, 21 and 28 days after the first treatments were applied are presented in Table 5 and Figure 3a. The analysis was done on the angular transformed data and back-transformed means are also presented. At the assessment one day before treatments were applied, there was significantly less flower damage in all treatments when

compared with the water control (P<0.05), but a significant effect was not seen in any treatment three or six days after the first treatments were applied. At the assessments 14 and 21 days after the first treatment, all treatments significantly reduced percentage flower area damaged compared with the water control. At the 14 day assessment, all treatments were equally effective. At the 21 day assessment, Azatin was more effective than AHDB 9964 and AHDB 9951 in a tank mix with Attracker. On the final assessment date, 28 days after the first treatment, only Actara, AHDB 9933 in a tank mix with Attracker and Azatin significantly reduced percentage flower area damaged compared with the water control and both Actara and Azatin were more effective than AHDB 9933 in a tank mix with Attracker.

Table 5. Mean percentage flower area damaged -1, 3, 6, 14, 21 and 28 days after the first treatment. Angular transformed data (back-transformed means in parenthesis). **Significantly fewer than on the water control (P<0.05).** Values sharing the same letters are not significantly different, those with different letters are significantly different. N.S.= not significant P value.

Date	5 July (-1 day)	9 July (day 3)	12 July (day 6)	20 July (day 14)	27 July (day 21)	3 Aug (day 28)
Treatment						
Water -ve control	9.81 b (2.91)	6.21 (1.17)	10.09 (3.07)	13.88 b (5.76)	21.23 c (13.11)	23.58 d (16.0)
Actara +ve control	**2.87 a** (0.25)	1.10 (0.04)	2.69 (0.22)	**5.02 a** (0.77)	**6.92 ab** (1.45)	**8.84 ab** (2.36)
AHDB 9933 + Attracker	**4.51 a** (0.62)	4.74 (0.68)	5.32 (0.86)	**5.50 a** (0.92)	**9.89 ab** (2.95)	**13.47 bc** (5.43)
AHDB 9970	**4.73 a** (0.68)	2.38 (0.17)	2.87 (0.25)	**6.94 a** (1.46)	**12.20 ab** (4.47)	16.88 cd (8.43)
Azatin	**4.38 a** (0.58)	3.78 (0.43)	5.80 (1.02)	**4.30 a** (0.56)	**5.24 a** (0.83)	**4.41 a** (0.59)
Majestik	**4.20 a** (0.54)	3.19 (0.31)	4.71 (0.67)	**7.01 a** (1.49)	**10.24 ab** (3.16)	22.65 d (14.83)
AHDB 9964	**4.06 a** (0.5)	2.34 (0.17)	7.12 (1.54)	**5.84 a** (1.03)	**13.76 b** (5.66)	16.80 cd (8.35)
AHDB 9951 + Attracker	**4.13 a** (0.52)	2.29 (0.16)	4.65 (0.66)	**4.92 a** (0.74)	**13.97 b** (5.83)	17.87 cd (9.42)
F value	2.88	1.50	2.04	4.69	4.43	7.41
P value	0.018	0.199 (N.S.)	0.078 (N.S.)	0.001	0.002	0.001
d.f.	34	35	35	35	30	32
s.e.d.	1.738	1.869	2.366	1.999	3.316	3.383
l.s.d.	3.532	3.795	4.804	4.057	6.772	6.890

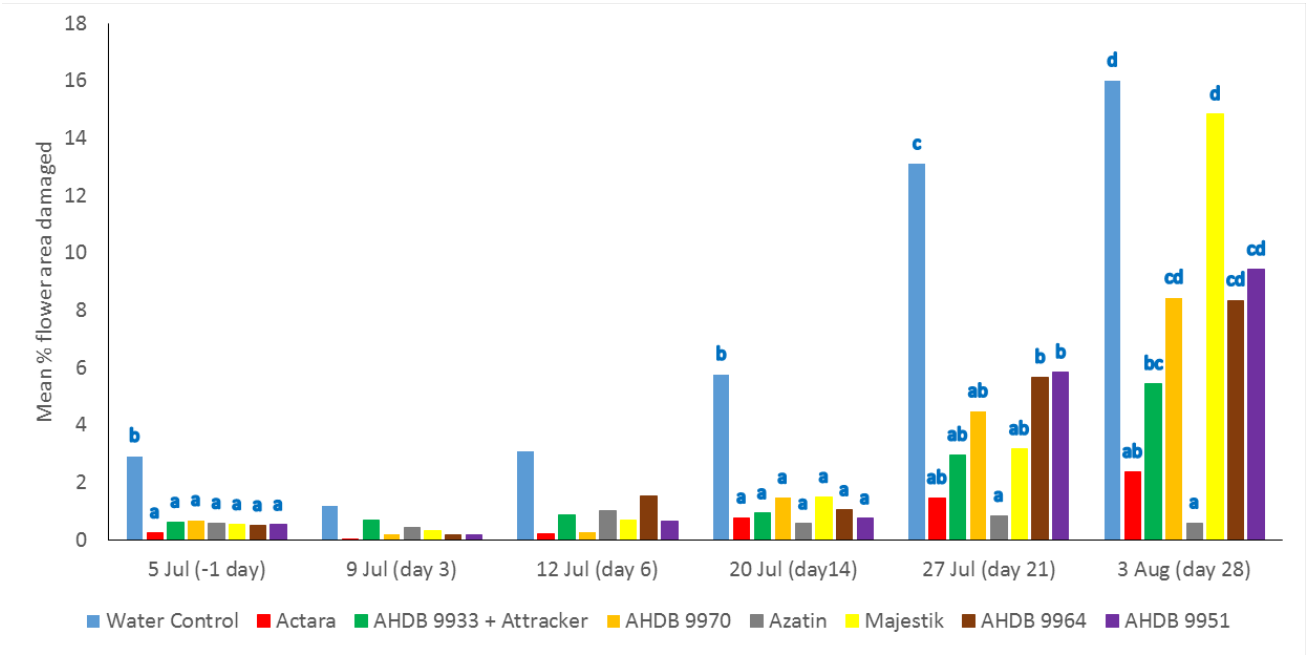

Figure 3a. Mean percentage flower area damaged -1, 3, 6, 14, 21 and 28 days after the first treatment. Back-transformed data shown (angular transformed data used for analysis). Values sharing the same letters are not significantly different, those with different letters are significantly different.

Percentage of flower area damaged without water controls

As significantly more flower damage was recorded on the water control plants than in the other treatments the day before treatments were applied (-1 day), results were also analysed after removing the water control data as this may have affected numbers in the water controls on subsequent assessment dates compared with those in other treatments. This data is shown in Figure 3b. No significant differences between treatments were given until the final assessment 28 days after first treatments, when Azatin was more effective than all treatments except for Actara. On this date, AHDB 9933 plus Attracker was equally effective as Actara.

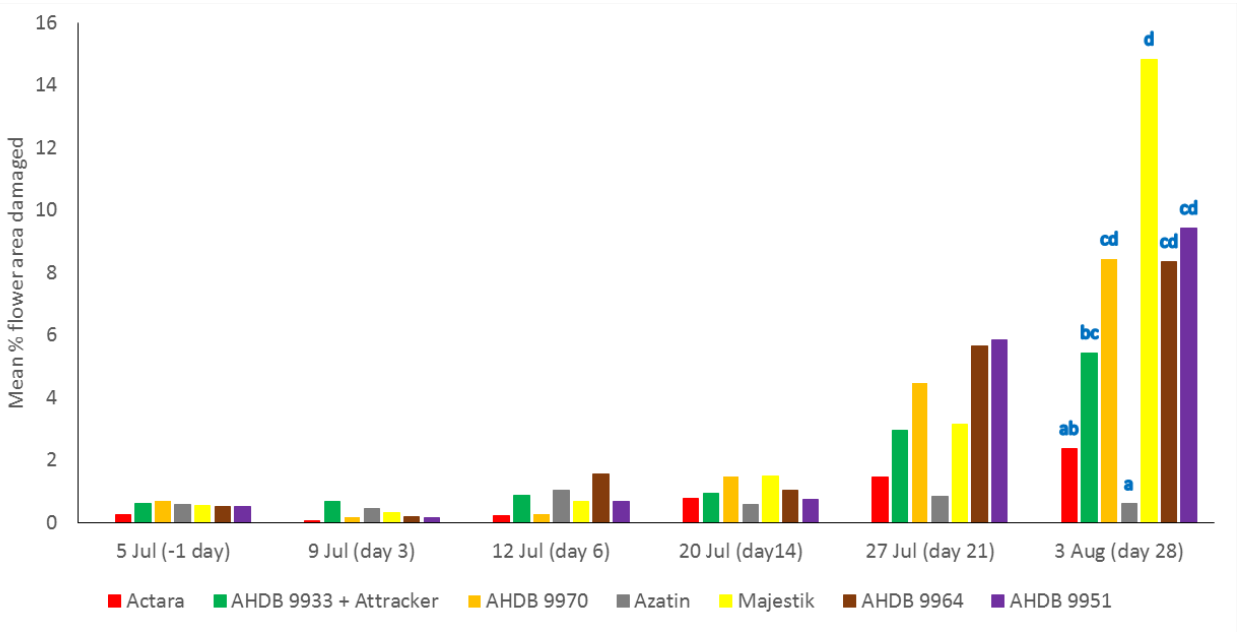

Figure 3b. Mean percentage flower area damaged -1, 3, 6, 14, 21 and 28 days after the first treatment. Back-transformed data shown (angular transformed data used for analysis). Water control data was removed from analysis. Values sharing the same letters are not significantly different, those with different letters are significantly different.

Abbott's formula was used to calculate percentage reduction in mean percentage flower damage compared with the water controls and these are presented in Table 6.

Table 6. Percentage reduction in mean percentage flower damage (back-transformed data shown) compared with Treatment 1 (water control) 3, 6, 14, 21 and 28 days after the first treatment (Abbott's formula). **Significantly fewer than on the water control (P<0.05).** No figure is given compared with T1 if there was no significant treatment effect on that date.

Date	9 July (day 3)	12 July (day 6)	20 July (day 14)	27 July (day 21)	3 Aug (day 28)
Treatment					
Water control					
Actara +ve control			**63.81**	**67.40**	**62.51**
AHDB 9933 + Attracker			**60.35**	**53.41**	**42.88**
AHDB 9970			**50.0**	**42.53**	28.41
Azatin			**69.04**	**75.32**	**81.30**
Majestik			**49.53**	**51.77**	3.94
AHDB 9964			**57.96**	**35.19**	28.75
AHDB 9951 + Attracker			**64.52**	**34.20**	24,22

Numbers of WFT adults on leaves

There were no significant differences in mean numbers of live WFT adults on leaves one day before first treatments were applied. Mean numbers of live WFT adults on leaves were significantly lower in all treatments compared with the water control three, six and 14 days after first treatments were applied and all treatments were equally effective (Table 7 and Figure 4). At the assessment 21 days after the first treatment, all treatments except for AHDB 9970, Majestik and AHDB 9964 significantly reduced mean numbers of WFT larvae on leaves and the effective treatments were all equally effective. At the final assessment, 28 days after

first treatments were applied, all treatments except for Majestik significantly reduced mean numbers of WFT larvae on leaves and all effective treatments were equally effective.

Table 7. Mean numbers of live WFT adults on leaves -1, 3, 6, 14, 21 and 28 days after the first treatment. **Significantly fewer than on water controls (P<0.05).** Values sharing the same letters are not significantly different, those with different letters are significantly different. N.S. = not significant P value.

Date	5 July (-1 day)	9 July (day 3)	12 July (day 6)	20 July (day 14)	27 July (day 21)	3 Aug (day 28)
Treatment						
Water -ve control	1.17	2.46 b	2.79 b	8.92 b	6.92 c	17.71 d
Actara +ve control	0.92	**0.29 a**	**0.25 a**	**1.83 a**	**1.50 a**	**4.08 ab**
AHDB 9933 + Attracker	1.13	**1.04 a**	**0.58 a**	**1.96 a**	**3.12 ab**	**5.0 ab**
AHDB 9970	1.08	**0.50 a**	**0.38 a**	**3.25 a**	6.29 bc	**10.79 bc**
Azatin	0.54	**0.50 a**	**0.46 a**	**1.08 a**	**0.75 a**	**1.79 a**
Majestik	0.96	**0.71 a**	**0.67 a**	**4.83 a**	4.88 bc	16.25 cd
AHDB 9964	1.04	**0.63 a**	**0.67 a**	**2.83 a**	5.29 bc	**9.92 bc**
AHDB 9951 + Attracker	0.75	**0.54 a**	**0.71 a**	**2.38 a**	**3.21 ab**	**8.17 ab**
F value	0.53	5.28	4.16	3.11	4.61	6.41
P value	0.806 (N.S.)	0.001	0.002	0.012	0.001	0.001
d.f.	35	35	35	35	35	35
s.e.d.	0.410	0.425	0.566	2.007	1.461	3.167
l.s.d.	0.833	0.864	1.148	4.074	2.965	6.430

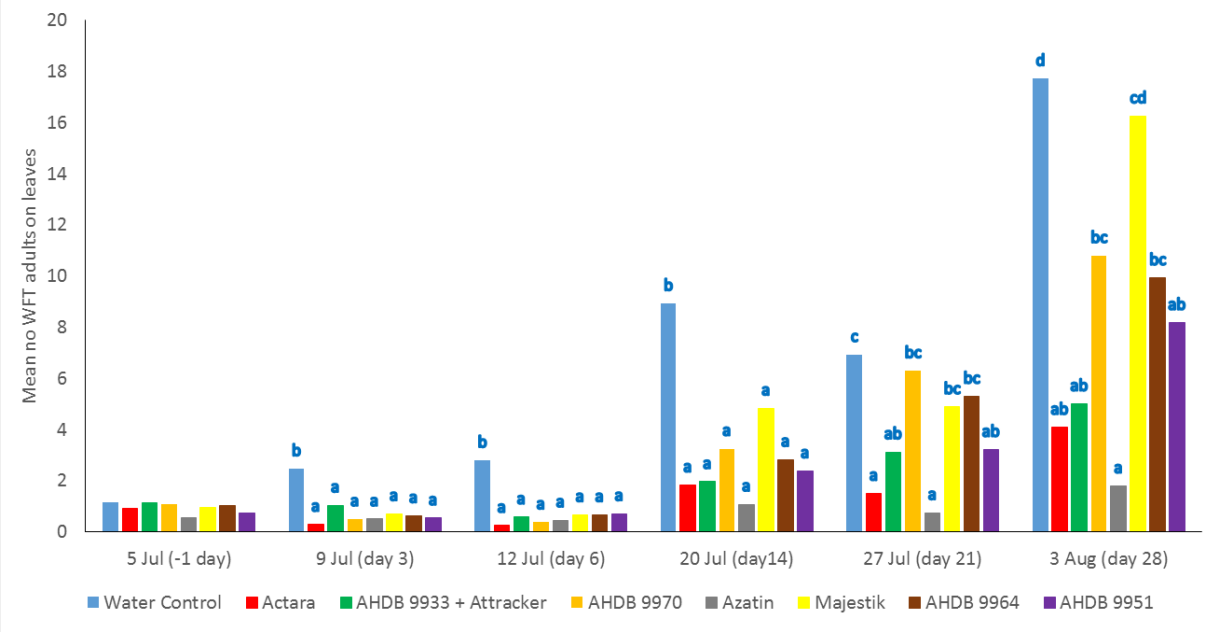

Figure 4. Mean numbers of live WFT adults on leaves -1, 3, 6, 14, 21 and 28 days after the first treatment. Values sharing the same letters are not significantly different, those with different letters are significantly different.

Abbott's formula was used to calculate percentage reduction in mean numbers of WFT adults on leaves compared with the water controls and these are presented in Table 8.

Table 8. Percentage reduction in mean numbers of WFT adults on leaves compared with Treatment 1 (water control) 3, 6, 14, 21 and 28 days after the first treatment (Abbott's formula). **Significantly fewer than on the water control (P<0.05).** No figure is given compared with T1 if there was no significant treatment effect on that date.

Date	9 July (day 3)	12 July (day 6)	20 July (day 14)	27 July (day 21)	3 Aug (day 28)
Treatment					
Water control					
Actara +ve control	**88.13**	**91.14**	**79.44**	**78.31**	**76.94**
AHDB 9933 + Attracker	**57.63**	**79.11**	**79.04**	**54.82**	**71.76**
AHDB 9970	**79.66**	**86.57**	**63.55**	9.04	**39.06**
Azatin	**79.66**	**83.58**	**87.85**	**89.16**	**89.88**
Majestik	**71.19**	**76.12**	**45.80**	29.52	8.23
AHDB 9964	**74.58**	**76.12**	**68.23**	23.49	**44.0**
AHDB 9951 + Attracker	**77.96**	**74.63**	**73.37**	**53.62**	**53.88**

Numbers of WFT larvae on leaves

No WFT larvae were recorded on leaves one day before the first treatments were applied. Mean numbers of live WFT larvae on leaves were significantly reduced by all treatments three days after the first treatments were applied compared with the water control and all treatments were equally effective (Table 9 and Figure 5). Six days after the first treatments were applied, all treatments except for AHDB 9970 and Majestik significantly reduced mean numbers of live larvae on leaves and all effective treatments were equally effective. Fourteen days after the first treatments were applied, all treatments except for AHDB 9970, Majestik

and AHDB 9964 significantly reduced mean numbers of larvae on leaves and all effective treatments were equally effective. At the assessments 21 and 28 days after the first treatments were applied, all treatments except for Majestik significantly reduced mean numbers of larvae on leaves and at the 28 day assessment Azatin was more effective than AHDB 9970 and AHDB 9964.

Table 9. Mean numbers of live WFT larvae on leaves 3, 6, 14, 21 and 28 days after the first treatment. **Significantly fewer than on the water control (P<0.05).** Values sharing the same letters are not significantly different, those with different letters are significantly different. N.S. = not significant P value.

Date	9 July (day 3)	12 July (day 6)	20 July (day 14)	27 July (day 21)	3 Aug (day 28)
Treatment					
Water -ve control	4.21 b	8.21 b	4.12 c	32.04 b	71.5 d
Actara +ve control	**1.25 a**	**2.58 a**	**0.25 a**	**4.54 a**	**17.5 ab**
AHDB 9933 + Attracker	**1.58 a**	**3.33 a**	**1.08 ab**	**3.38 a**	**17.9 ab**
AHDB 9970	**1.79 a**	4.87 ab	1.71 abc	**12.50 a**	**40.2 bc**
Azatin	**1.12 a**	**2.37 a**	**1.17 ab**	**1.17 a**	**6.9 a**
Majestik	**2.12 a**	5.08 ab	3.54 bc	34.79 b	61.2 cd
AHDB 9964	**1.92 a**	**3.58 a**	2.83 abc	**15.96 a**	**37.1 bc**
AHDB 9951 + Attracker	**0.54 a**	**2.18 a**	**1.0 ab**	**9.42 a**	**27.7 ab**
F value	2.40	2.34	2.74	6.54	6.23
P value	0.041	0.046	0.022	0.001	0.001
d.f.	35	35	35	35	35
s.e.d.	0.994	1.858	1.175	7.092	12.67
l.s.d.	2.019	3.771	2.385	14.397	25.72

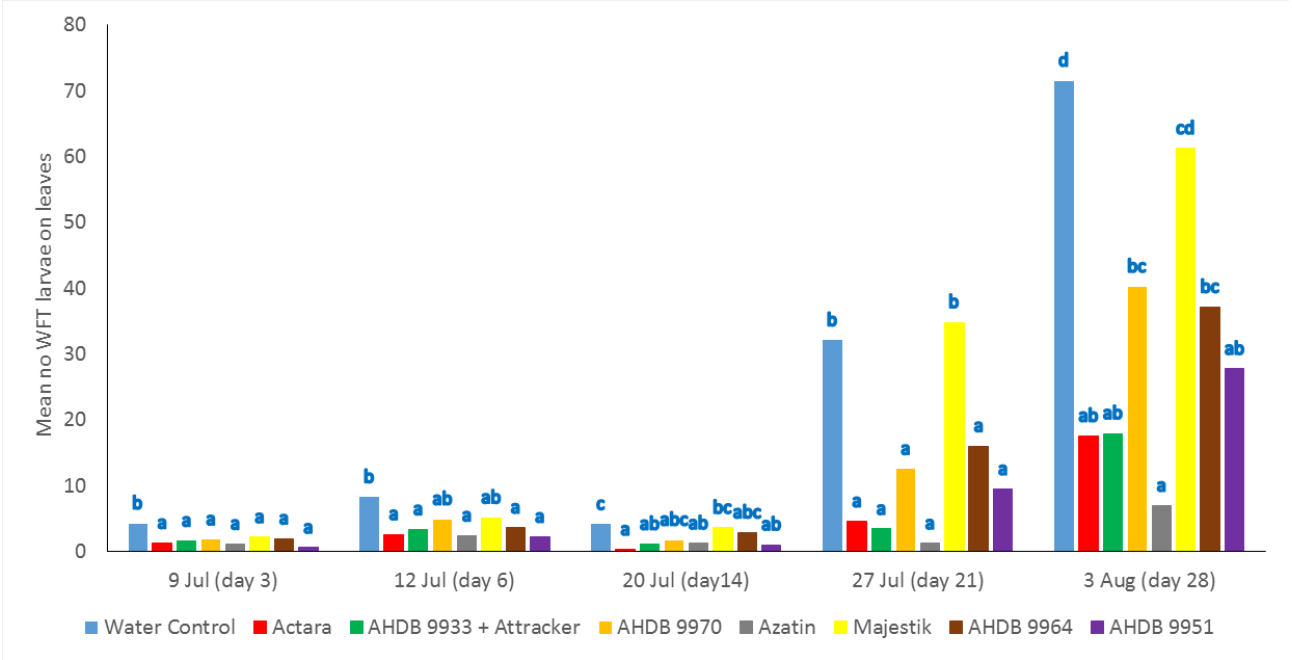

Figure 5. Mean numbers of live WFT larvae on leaves 3, 6, 14, 21 and 28 days after the first treatment. Values sharing the same letters are not significantly different, those with different letters are significantly different.

Abbott's formula was used to calculate percentage reduction in mean numbers of WFT larvae on leaves compared with the water controls and these are presented in Table 10.

Table 10. Percentage reduction in mean numbers of WFT larvae on leaves compared with Treatment 1 (water control) 3, 6, 14, 21 and 28 days after the first treatment (Abbott's formula). **Significantly fewer than on the water control (P<0.05).** No figure is given compared with T1 if there was no significant treatment effect on that date.

Date	9 July (day 3)	12 July (day 6)	20 July (day 14)	27 July (day 21)	3 Aug (day 28)
Treatment					
Water control					
Actara +ve control	**70.29**	**68.53**	**93.94**	**85.83**	**75.59**
AHDB 9933 + Attracker	**62.38**	**59.39**	**73.75**	**89.48**	**75.02**
AHDB 9970	**57.41**	40.61	58.59	**60.99**	**43.85**
Azatin	**73.27**	**71.06**	**71.71**	**96.35**	**90.40**
Majestik	**49.50**	38.07	14.13	-8.58	14.50
AHDB 9964	**54.44**	**56.35**	31.32	**50.19**	**48.28**
AHDB 9951 + Attracker	**87.12**	**72.99**	**75.76**	**70.60**	**61.32**

Percentage of leaf area damaged

The mean percentage leaf area damaged the day before treatments were applied and three, six, 14, 21 and 28 days after the first treatments were applied are presented in Table 11 and Figure 6. The analysis was done on the angular transformed data and back-transformed means are also presented. At the assessment one day before treatments were applied (-1 day) there were no significant differences between treatments. At the assessments three and six days after the first treatments were applied, all treatments significantly reduced the mean percentage leaf area damaged compared with the water controls and all treatments were

equally effective. Fourteen days after the first treatments were applied, all treatments significantly reduced mean percentage leaf area damaged compared with the water control and Actara, AHDB 9933 in a tank mix with Attracker, Azatin, AHDB 9964 and AHDB 9951 in a tank mix with Attracker were more effective than Majestik. At the assessment 21 days after the first treatments were applied, all treatments significantly reduced the mean percentage leaf area damaged and Azatin was more effective than AHDB 9970, Majestik and AHDB 9964. On this date, Majestik was less effective than all treatments except for AHDB 9964 with which it was equally effective. On the final assessment date, 28 days after the first treatments, were applied, all treatments except for Majestik significantly reduced the mean percentage leaf area damaged compared with the water control. Azatin was more effective than AHDB 9970, Majestik and AHDB 9964. Actara was more effective than Majestik and AHDB 9964.

Table 11. Mean percentage leaf area damaged -1, 3, 6, 14, 21 and 28 days after the first treatment. Angular transformed data (back-transformed means in parenthesis). **Significantly fewer than on the water control (P<0.05).** Values sharing the same letters are not significantly different, those with different letters are significantly different. N.S. = not significant P value.

Date	5 July (-1 day)	9 July (day 3)	12 July (day 6)	20 July (day 14)	27 July (day 21)	3 Aug (day 28)
Treatment						
Water -ve control	4.67 (0.66)	6.82 b (1.41)	9.38 b (2.66)	14.41 c (6.19)	24.68 e (17.43)	42.15 e (45.03)
Actara +ve control	1.36 (0.06)	**1.57 a** (0.07)	**4.24 a** (0.55)	**6.06 a** (1.11)	**7.56 ab** (1.73)	**10.57 ab** (3.36)
AHDB 9933 + Attracker	2.87 (0.25)	**3.1 a** (0.29)	**4.29 a** (0.56)	**6.01 a** (1.10)	**7.11 ab** (1.53)	**12.27 abc** (4.52)
AHDB 9970	2.49 (0.19)	**2.99 a** (0.27)	**5.72 a** (0.99)	**8.32 ab** (2.09)	**11.83 bc** (4.20)	**22.79 bc** (15.0)
Azatin	2.04 (0.13)	**2.40 a** (0.18)	**3.99 a** (0.48)	**6.16 a** (1.15)	**6.02 a** (1.10)	**7.55 a** (1.73)
Majestik	2.06 (0.13)	**3.54 a** (0.38)	**5.67 a** (0.98)	**10.62 b** (3.40)	**17.02 d** (8.57)	37.11 de (36.40)
AHDB 9964	2.70 (0.22)	**2.63 a** (0.21)	**5.25 a** (0.84)	**6.97 a** (1.47)	**13.12 cd** (5.15)	**24.85 cd** (17.66)
AHDB 9951 + Attracker	1.50 (0.07)	**2.37 a** (0.17)	**4.79 a** (0.70)	**6.47 a** (1.27)	**9.81 abc** (2.90)	**14.71 abc** (6.45)
F value	1.83	4.95	5.34	7.68	13.75	8.51
P value	0.112 (N.S.)	0.001	0.001	0.001	0.001	0.001
d.f.	35	35	35	35	35	35
s.e.d.	1.088	1.007	1.060	1.524	2.374	6.155
l.s.d.	2.208	2.045	2.151	3.095	4.820	12.496

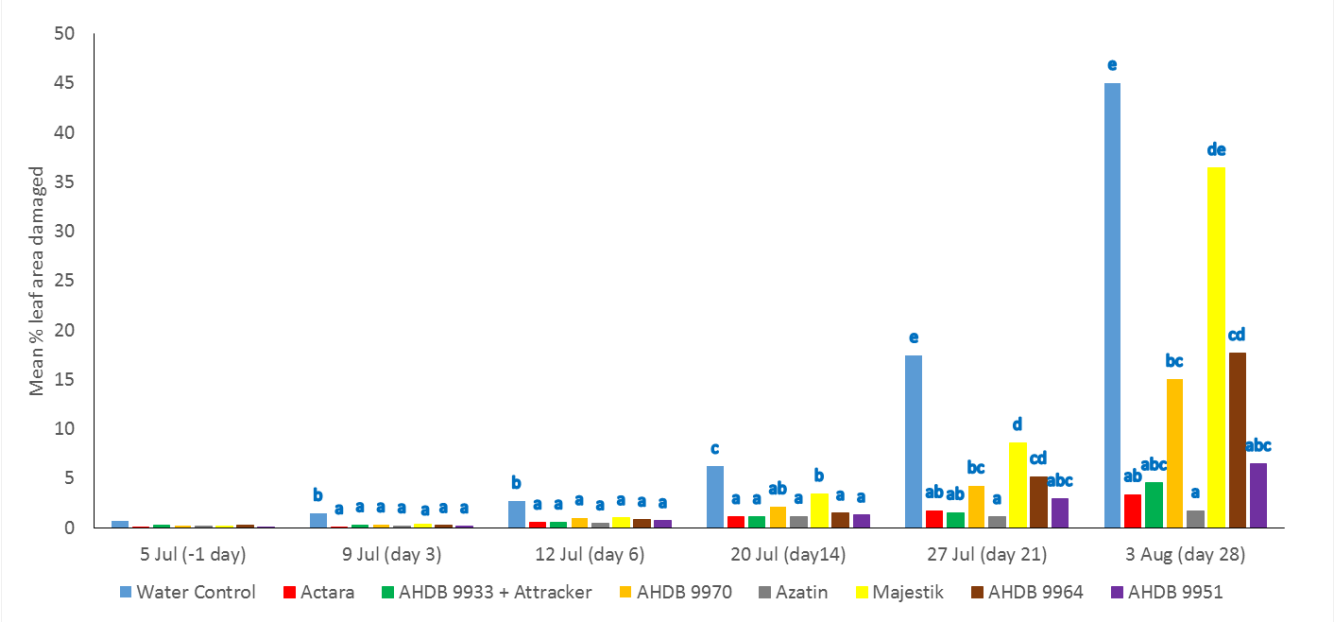

Figure 6. Mean percentage leaf area damaged -1, 3, 6, 14, 21 and 28 days after the first treatment. Back-transformed data shown (angular transformed data used for analysis).Values sharing the same letters are not significantly different, those with different letters are significantly different.

Abbott's formula was used to calculate percentage reduction in mean numbers of WFT larvae on leaves compared with the water controls and these are presented in Table 12.

Table 12. Percentage reduction in mean back-transformed percentage leaf damage compared with Treatment 1 (water control) 3, 6, 14, 21 and 28 days after the first treatment (Abbott's formula). **Significantly fewer than on water controls (P<0.05).** No figure is given compared with T1 if there was no significant treatment effect on that date.

Date	9 July (day 3)	12 July (day 6)	20 July (day 14)	27 July (day 21)	3 Aug (day 28)
Treatment					
Water control					
Actara +ve control	**77.04**	**54.77**	**57.97**	**69.37**	**74.92**
AHDB 9933 + Attracker	**54.51**	**54.27**	**58.28**	**71.19**	**70.89**
AHDB 9970	**56.22**	**39.02**	**42.24**	**52.07**	**45.93**
Azatin	**64.76**	**57.47**	**57.27**	**75.61**	**82.09**
Majestik	**48.16**	**39.55**	**26.26**	**31.04**	11.96
AHDB 9964	**61.38**	**44.08**	**51.60**	**46.84**	**41.04**
AHDB 9951 + Attracker	**65.23**	**48.94**	**55.13**	**60.25**	**65.10**

Phytotoxicity
No phytotoxicity symptoms were observed on any assessment date.

Discussion

- The first treatments were applied four days after releasing 30 WFT adults into each replicate cage. At the first assessment one day before applying first treatments (three

days after WFT release) significantly more flower damage was recorded on the water control plants than in all other treatments. On the same date, higher numbers of WFT adults per flower were recorded on the water control plants than in other treatments, although this difference was not statistically significant. However, as the higher numbers of adults and higher percentage flower area damaged in the water controls may have affected the relationship between the data in the water controls and the other treatments on subsequent assessment dates, the data on numbers of adults per flower and percentage flower damage were analysed both with and without the water control data on all assessment dates. When the water controls were removed from the analysis of mean numbers of WFT adults per flower, as when the water controls were included, significant differences were only given on the final assessment 28 days after first treatments and the differences between treatments were the same in both analyses. When the water controls were removed from the analysis of mean percentage flower area damaged, there were no significant differences between treatments on the 21 day assessment, whereas when the water controls were included, Azatin was more effective than AHDB 9964 and AHDB 9951 in a tank mix with Attracker. At the day 28 assessment, the differences between treatments were the same in both analyses.

- The standard insecticide Actara performed against WFT as expected, confirming it to be a suitable positive control to use in the experiment. Actara has an EAMU for use on protected ornamentals but is not currently used by growers for control of WFT as it is one of the neonicotinoids currently subject to EC restrictions on use on flowering plants. However it was useful as a research tool in this experiment.
- The botanical biopesticide Azatin is approved for use on protected ornamentals with a label recommendation for use against western flower thrips and was as effective as Actara on all assessment dates. Azatin gave over 90% control of WFT adults and larvae per flower on the final three assessment dates and at least 90% control of adults and larvae on leaves on the final two assessment dates.
- The conventional insecticides AHDB 9933 and AHDB 9951 were both used in tank mixes with the sugars product Attracker on the recommendation of the manufacturers of each product. Neither of these coded products is yet approved or has an EAMU for use on protected ornamentals in the UK.
- The biopesticide AHDB 9964 does not currently have an approval or EAMU for use in the UK.
- The biopesticide AHDB 9970 is currently approved for use on protected edible crops in the UK and since the completion of this experiment has gained an EAMU for use on fully protected ornamentals and thus can be named as Flipper.
- Majestik is approved for use on all outdoor and protected crops for the control of spider mites and thus could be used on protected ornamentals for incidental control of WFT.
- The experimental treatments were applied separately at spray intervals recommended by the manufacturers in order to test efficacy. In practice, growers are likely to use a combination of treatments as needed, following resistance management guidelines within an IPM programme

Conclusions

- The botanical biopesticide Azatin applied four times at 7-day intervals was as effective as the standard positive control Actara applied twice at 7-day intervals in reducing mean numbers WFT adults, larvae and percentage flower and leaf area damaged compared with the water controls on all assessment dates.
- The conventional insecticide AHDB 9933, applied in a tank mix with the sugars product Attracker, applied twice at 7-day intervals was as effective as Azatin at all assessments except for 28 days after first treatments when it was less effective in reducing percentage flower damage.
- The conventional insecticide AHDB 9951 applied in a tank mix with Attracker four times at 7-day intervals was also as effective as Azatin at all assessments except for

28 days after first treatments when it was less effective in reducing percentage flower damage.

- The biopesticide AHDB 9970 (Flipper) and the botanical biopesticide AHDB 9964, both applied four times at 7-day intervals were equally effective on all assessment dates. Both treatments were as effective as the above most effective three treatments until WFT numbers increased 21 and 28 days after first treatments. On day 21 they did not significantly reduce mean numbers of WFT adults on leaves compared with the water controls and they were less effective than Azatin at reducing mean percentage leaf area damaged. On day 28 they did not significantly reduce mean numbers of WFT adults per flower or percentage flower damage and Flipper did not significantly reduce mean numbers of WFT larvae per flower compared with the water controls. On day 28 both biopesticides were less effective than Azatin at reducing mean numbers of WFT adults and larvae on leaves and percentage leaf area damaged.
- The botanical biopesticide Majestik, applied seven times at 4-day intervals gave similar reductions in WFT numbers and damage as the other treatments whilst WFT numbers remained low. When WFT numbers had increased by day 21, Majestik did not significantly reduce mean numbers of adults or larvae on leaves. At the final assessment on day 28, Majestik was the least effective treatment, when it did not significantly reduce mean numbers of WFT adults or larvae per flower or on leaves or percentage flower or leaf area damage compared with the water controls.
- No treatments caused phytotoxic effects.

Acknowledgements

With thanks to the AHDB for funding and supporting this project and for the financial and in kind contributions from the crop protection manufactures and distributors involved with the SCEPTREplus programme as listed below:
Agrii, Alpha Biocontrol Ltd, Andermatt, Arysta Lifescience, BASF, Bayer, Belchim, Bionema Limited, Certis Europe, Dow, DuPont, Eden Research, Fargro Limited, FMC, Gowan, Interfarm, Lallemand Plant Care, Novozymes, Oro Agri, Russell IPM, Sumitomo Chemicals, Syngenta, UPL.

Appendix

a. Crop diary – events related to growing crop

Crop	Cultivar	Potting up date	Pots per cage
Verbena	Quartz	14/5/18	4

Biological control agents applied for other pests

Date	Product	Rate per cage	Pest
21-June	*Aphidius colemani*	20	*Myzus persicae*
29-June	*Aphidius colemani*	20	*Myzus persicae*
6-July	*Aphidius colemani*	20	*Myzus persicae*
20-July	*Aphidius colemani*	20	*Myzus persicae*

Details of irrigation regime
Plant were irrigated using automatic irrigation to capillary matting beneath the cages. The matting was kept damp throughout the trial.

b. Trial diary

14-May	Plug plants potted on
2-July	Trial plants selected and 30 WFT adults added to each cage
5-July	-1 day thrips numbers and damage assessment
6-July	Day 0 sprays applied
9-July	Day 3 thrips numbers and damage assessment
10-July	Day 4 Majestik spray
12-July	Day 6 thrips numbers and damage assessment
13-July	Day 7 sprays applied
14-July	Day 8 Majestik spray
18-July	Day 12 Majestik spray
19-July and 20 July	Day13/14 thrips numbers and damage assessment
20-July	Day 14 sprays applied
22-July	Day 16 Majestik spray
26-July	Day 20 Majestik spray
26-July	Day 21 thrips numbers and damage assessment
27-July	Day 21 sprays applied
30-July	Day 24 Majestik spray
2-August	Day 28 thrips numbers and damage assessment

c. Climatological data during study period

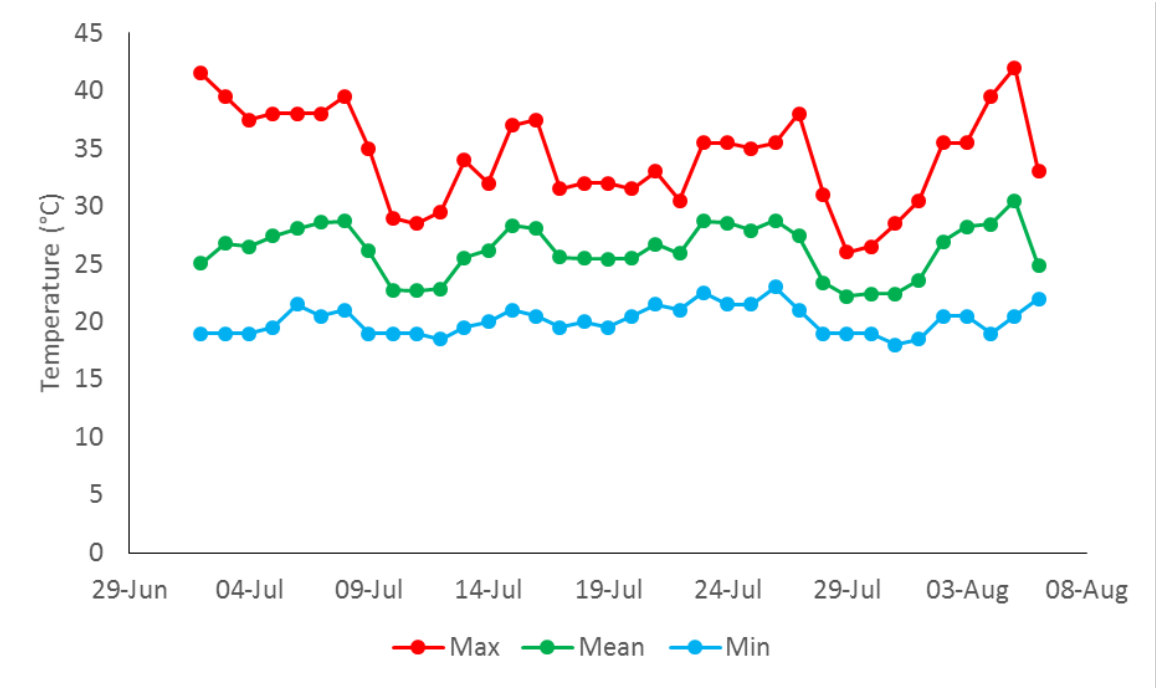

Figure 1. Mean daily mean, maximum and minimum temperatures inside a representative plot cage during the trial period Glasshouse compartment 3.

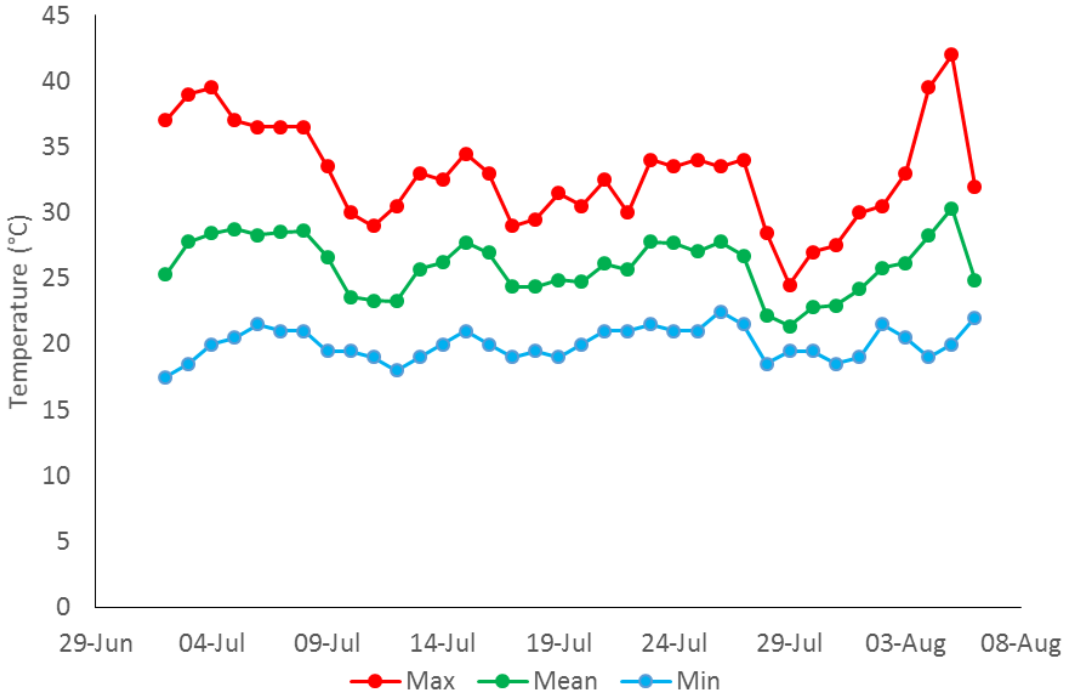

Figure 2. Mean daily mean, maximum and minimum temperatures inside a representative plot cage during the trial period Glasshouse compartment 4

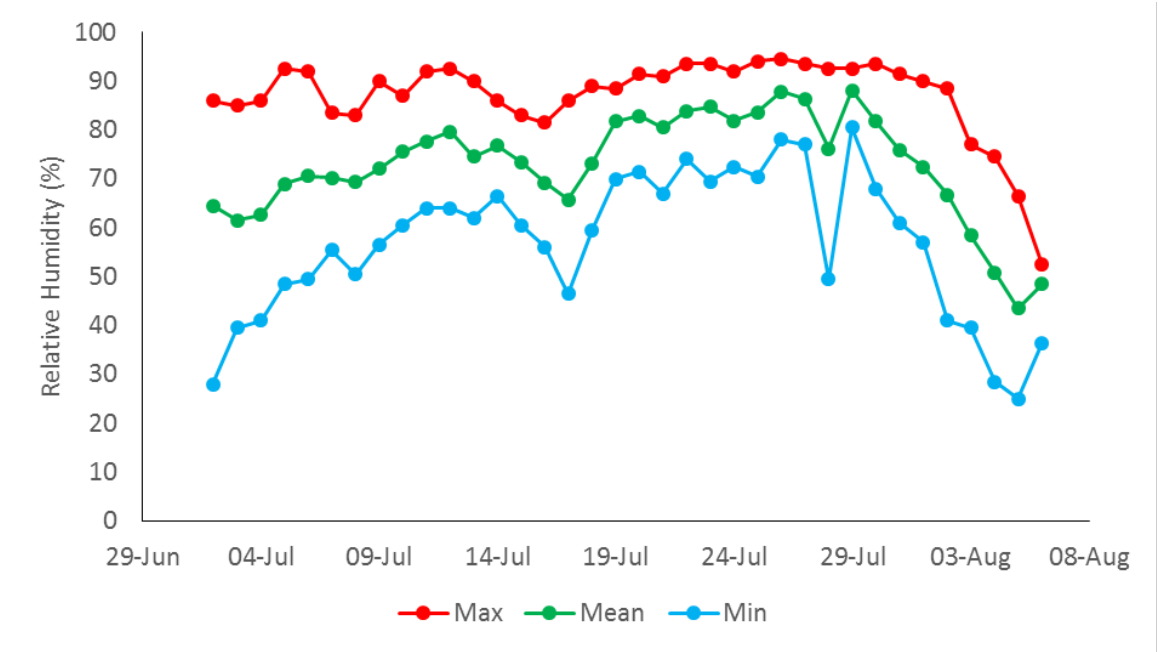

Figure 3. Mean daily mean, maximum and minimum relative humidities (%) inside a representative plot cage during the trial period in Glasshouse compartment 3.

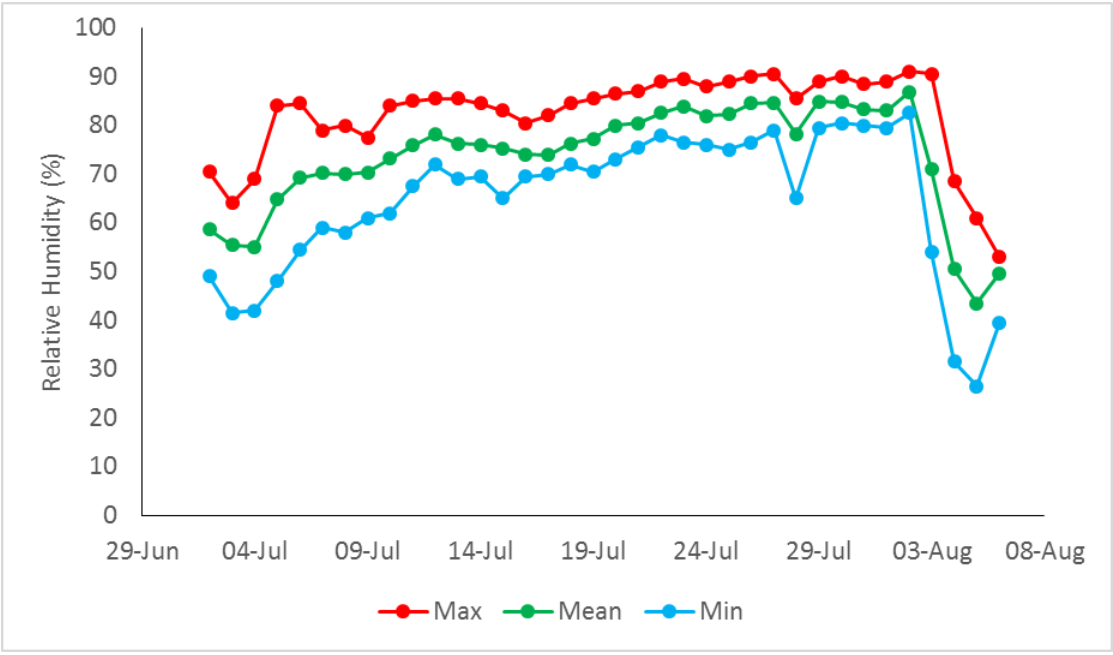

Figure 3. Mean daily mean, maximum and minimum relative humidities (%) inside a representative plot cage during the trial period in Glasshouse compartment 4.

d. Raw data (means) from assessments

Mean percentage flower area damaged before angular transformation

Date	5 July (-1 day)	9 July (day 3)	12 July (day 6)	20 July (day 14)	27 July (day 21)	3 Aug (day 28)
Treatment						
Water -ve control	3.19	1.35	3.92	6.24	15.2	16.29
Actara +ve control	0.58	0.10	0.47	1.21	1.9	2.56
AHDB 9933 + Attracker	0.99	1.15	1.37	1.44	3.1	6.88
AHDB 9970	0.96	0.28	0.33	1.81	4.6	9.06
Azatin	1.23	1.41	1.53	0.96	1.3	1.19
Majestik	1.09	0.65	1.11	3.0	5.0	17.41
AHDB 9964	1.28	0.39	1.81	1.75	7.8	9.28
AHDB 9951 + Attracker	0.65	0.26	1.04	0.96	8.4	9.92

Mean percentage leaf area damaged before angular transformation

Date	5 July (-1 day)	9 July (day 3)	12 July (day 6)	20 July (day 14)	27 July (day 21)	3 Aug (day 28)
Treatment						
Water -ve control	1.25	1.88	3.04	7.33	19.12	46.08
Actara +ve control	0.34	0.18	0.96	1.60	1.94	3.79
AHDB 9933 + Attracker	0.61	0.56	0.90	1.21	1.69	5.25
AHDB 9970	0.44	0.46	1.27	2.77	4.63	16.71
Azatin	0.34	0.36	0.69	1.29	1.12	1.90
Majestik	0.37	0.66	1.33	3.88	9.96	38.60
AHDB 9964	0.65	0.45	1.17	2.29	7.54	22.29
AHDB 9951 + Attracker	0.36	0.35	0.94	1.56	3.21	7.25

e. Trial design

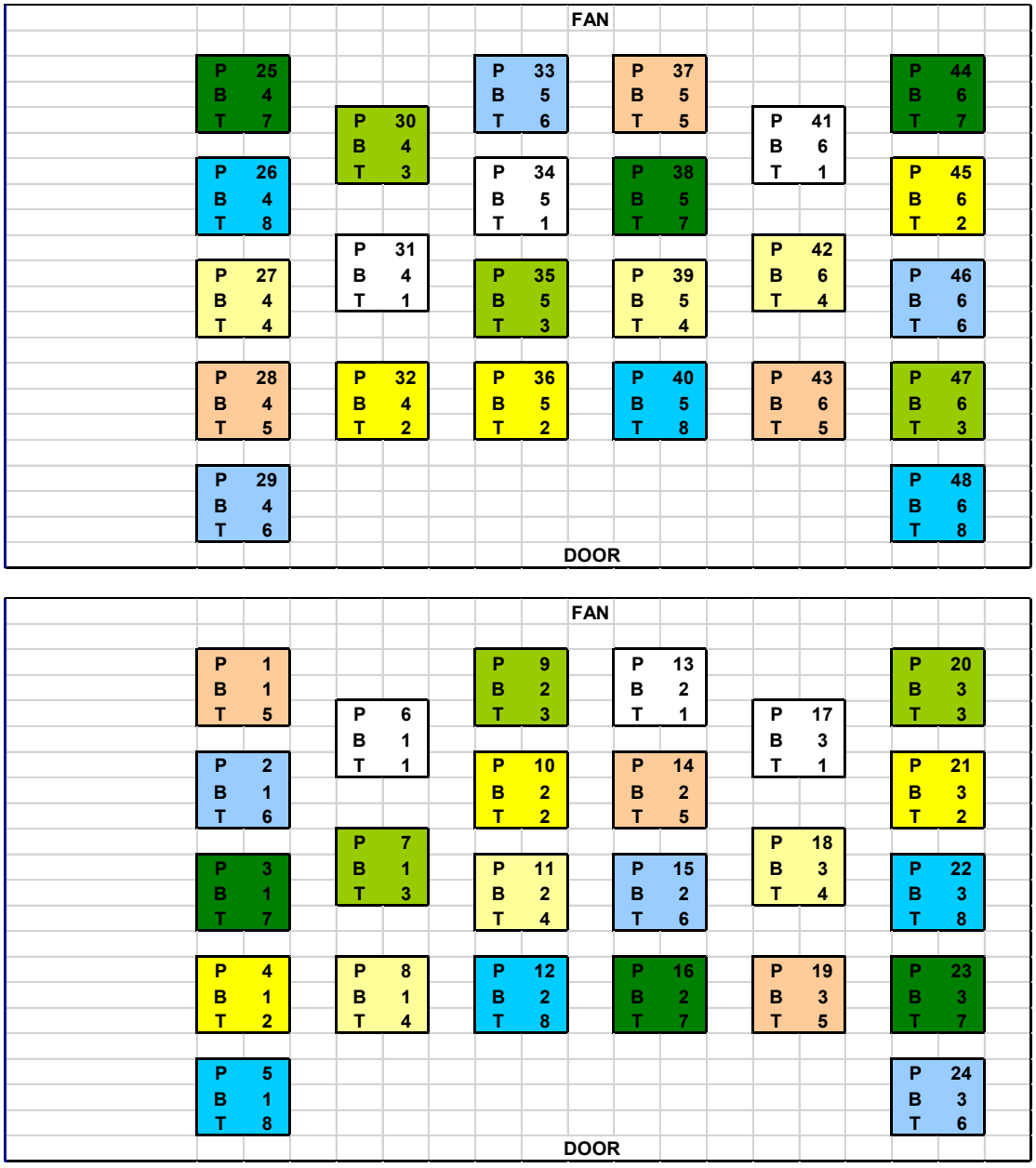

Figure 4. Trial plan in two adjacent glasshouse compartments 3 (top) and 4 (bottom). P= plot, B= block, T= treatment number, figures indicate plot numbers.

f. Spray deposition

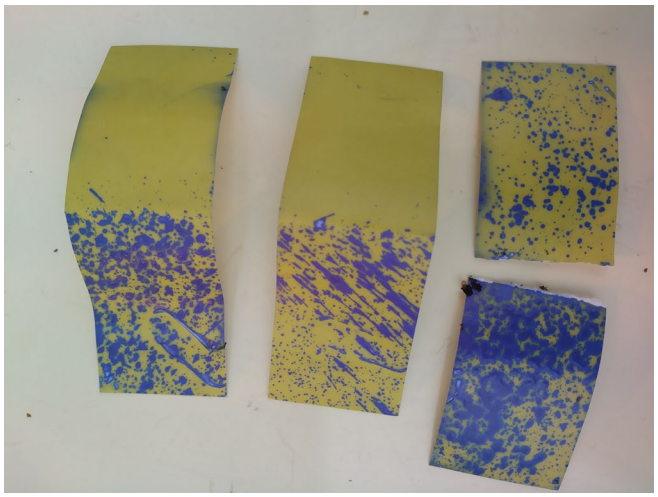

Figure 4. Water spray deposition on water-sensitive paper attached to top leaf (left, with top of paper being leaf underside and bottom of paper being leaf upper surface), lower leaf (centre, with top and bottom of paper as for top leaf), and on growing media (upper right, under lower leaf and lower right, exposed position).

g. 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