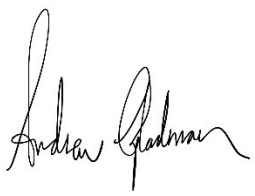
CP 205 AHDB Horticulture Efficacy Trials 2022
Final Trial Report

Work package:	WP9
Title:	Thrips control in cut flowers
Crop	Pot Chrysanthemum, trial data also applicable to other flowering cut flower and protected ornamentals.
Target	Onion thrips – *Thrips tabaci* - THRITB
Lead researcher:	Andrew Gladman
Organisation:	RSK ADAS, ADAS Boxworth, Battlegate Road, Boxworth, Cambridgeshire, CB23 4NN
Period:	October to December 2022
Report date:	14/03/2023
Report authors:	Andrew Gladman, Jude Bennison
ORETO Number:	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	Author's signature
14/03/2023	

Grower Summary

Introduction

Various thrips species can infest outdoor and protected cut flowers. The most common species on protected flowers is western flower thrips (WFT), *Franklinella occidentalis*, but the onion thrips, *Thrips tabaci* can also occur on protected and outdoor flowers, on protected vegetables and on outdoor allium crops. This project focussed on onion thrips, as it has a wide host range, and some UK populations are now resistant to pyrethroid insecticides. Onion thrips can also transmit *Iris yellow spot virus* which has occurred on *Lisianthus* in the UK. A previous SCEPTREplus trial (SP 05) revealed significant challenges in controlling onion thrips on field-grown leek, with the majority of evaluated chemical and biological plant protection products (PPPs) proving ineffective in limiting onion thrips damage. There are also recent reports from Canada that IPM strategies developed for the control of WFT are less effective against onion thrips on pot chrysanthemum. There is thus a need to identify IPM-compatible plant protection products (PPPs) to aid the control of onion thrips.

Methods

Two-week old, rooted pot chrysanthemum (cv. 'Rainbow Circus') plants were purchased from a commercial nursery and grown in thrips-proof cages in two heated glasshouse compartments at ADAS Boxworth between September and November 2022. Once the plants were five weeks old (five weeks until marketing), 40 onion thrips adult females were released into each cage. The first treatments were applied two weeks after thrips release, when leaf damage was evident in all plots. There were six replicate cages (plots) for each of the eight treatments. Treatments included six biological PPPs, one conventional insecticide and an untreated control. Treatments were evaluated relative to the untreated control and an approved industry standard product, azadirachtin (Azatin). All treatments were applied using an Oxford precision sprayer in 600L/ha water. Treatments were applied over a 26-day period at time intervals and frequencies recommended by product manufacturers. Application intervals ranged from every 3-7 days, while the number of applications ranged from 2-8. Assessments were undertaken prior to infestation, prior to the first treatments, and at weekly intervals for four weeks following the first treatments. Assessments included: (1) number of leaves with thrips damage (incidence) (2) Percentage of total leaf area damaged, (3) number of flowers with thrips damage (4) Percentage flower area damaged and (5) number of thrips on the upper and lower surface of two marked leaves per plant. At the final assessment, a destructive count of total onion thrips adults and larvae in flowers and on leaves was undertaken on all plants.

Results

- Mean numbers of thrips adults per plant (flowers plus leaves) at the final assessment were significantly reduced by Azatin, Eradicoat Max, AHDB 9730 and 9728, with reductions of 59.7%, 55%, 73.9% and 83.9% respectively compared with the untreated control. Azatin, the industry standard is approved for use on ornamentals under permanent protection with a label recommendation for the control of onion thrips and western flower thrips. Eradicoat Max is approved for use on all protected edible and non-edible crops, with a label recommendation for control of spider mites and whitefly.
- Total mean numbers of thrips (adults plus larvae) per plant (flowers plus leaves) on the final assessment were significantly reduced by AHDB 9728 and AHDB 9730, reducing numbers by 70.4% and 67.6% respectively. These treatments led to reductions comparable to Azatin.

- During the final assessment, most thrips adults and larvae were found in chrysanthemum flowers rather than on the leaves (untreated control means 7.54 in flowers, 2.75 on leaves).
- At all assessments, there were more adults than larvae in all treatments.
- When onion thrips on leaves and in flowers were considered separately, mean numbers of adults were significantly reduced in flowers by Azatin, AHDB 9730 and AHDB 9728, giving 66.9%, 74.5% and 82.8% reductions respectively compared with the untreated control. While no treatment significantly reduced thrips numbers on leaves relative to untreated controls, there was a notable trend for lower thrips numbers on leaves treated with AHDB 9728 and AHDB 9730.
- While no significant differences were seen in flower damage incidence and percentage flower area damaged between treatments, a trend was observed at the final assessment of lower numbers of flowers damaged and less flower area damaged on plants treated with AHDB 9728 relative to all other treatments.
- Significant differences between treatments in incidence of leaves damaged by onion thrips was only found on the final trial assessment date, with AHDB 9728 significantly reducing leaves damaged by 48.1% relative to the untreated control.
- Owing to the lack of difference seen in flower damage even when treatments reduced numbers of thrips, this trial highlights that it is paramount for growers of ornamental crops to not rely on plant protection products for control of onion thrips, but to use them as part of an IPM programme including the preventive use of biological control agents such as predatory mites and in the case of pot chrysanthemum, entomopathogenic nematodes. This will help to manage thrips populations before the buds and flowers open. Azatin, Eradicoat Max, AHDB 9728 and AHDB 9730 are compatible with beneficials used in IPM programmes.

Take home message:
The results of this trial have demonstrated the efficacy of Azatin and Eradicoat Max against onion thrips and also two currently unapproved treatments, AHDB 9728 and AHDB 9730, which may be of value to growers for the control of onion thrips on protected ornamentals and cut flowers. Although these four treatments reduced numbers of onion thrips, flower damage was not reduced, illustrating that even low numbers of thrips can still cause flower damage. These plant protection products should not be relied on for control of onion thrips but should be used as part of an IPM programme together with preventive use of biological control agents.

SCIENCE SECTION

Objectives

1. To conduct an efficacy and crop safety trial testing IPM-compatible conventional plant protection products and bioprotectant products for control of onion thrips (*Thrips tabaci*) on Chrysanthemum and to communicate the results to the industry.
2. To monitor the treated crop for phytotoxicity

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
EPPO PP1/135(4)	Phytotoxicity assessment	None
EPPO PP1/152(3)	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 PP 1/160(2)	Thrips on glasshouse crops	(1) Size of cages and flowering stage of plants limited the number of plants per plot to 4 rather than a suggested minimum of 15. (2) Six replicate plots were undertaken for each treatment rather than the minimum of four. (3) Owing to unknown speed of damage and reproduction of onion thrips on chrysanthemum, assessments were spread over a 4-week period rather than the suggested 7–8-day period. (4) Owing to the smaller size of *T. tabaci* than F*rankliniella occidentalis,* rather than at each assessment, complete thrips numbers were counted only on the final assessment date. Numbers of thrips on 8 leaves per plot were however recorded at each assessment. (5) Leaf and flower damage assessments were taken at each date. Such assessments are not referenced in EPPO guidelines.

Test site

Item	Details
Location address	ADAS Boxworth, Boxworth, Cambridge, CB23 4NN
Crop	Pot *Chrysanthemum*

Cultivar	'Rainbow Circus'
Soil or substrate type	Levington M2 Compost
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:	Six randomised blocks spread across two glasshouse compartments (3 blocks per compartment)
Number of replicates:	6
Row spacing:	1L pots arranged in two rows of two
Plot size: (w x l)	0.5 x 0.5m thrips-proof cage
Plot size: (m^2)	0.125m^2
Number of plants per plot:	4
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	Application interval	Number of applications in trial
	n/a	Untreated control	n/a	n/a	n/a	n/a	n/a
-	Azadirachtin	Azatin	71871681	26g/L	EC	7-day interval	4
AHDB 9730	Confidential					7-day interval	4
AHDB 9728	Confidential					7-day interval	4
-	Maltodextrin	Eradicoat® Max	37625	598g/L	SC	3-day interval	8
AHDB 9768	Confidential					4-day interval	4
AHDB 9729	Confidential					7-day interval	4
AHDB 9821	Confidential					5-day interval	2

Application schedule

Treatment number	Treatment: product name or AHDB code	Rate of active substance (when applied at 600L/ha) (ml or g a.s./ha)	Rate of product (l or kg/ha)	Application code
1	Untreated control	n/a	n/a	n/a
2	Azatin	21.84g/ha	0.84L/ha (140ml per 100L)	ADHJ
3	AHDB 9730	Not for disclosure	3.6L/ha (0.6% concentration)	ADHJ
4	AHDB 9728	Not disclosed	3.75L/ha	ADHJ
5	Eradicoat® Max	7176g/ha	12L/ha [20ml/L] (2% concentration)	ABDFHIJK
6	AHDB 9768	Not for disclosure	2kg/ha	ABEG
7	AHDB 9729	Not disclosed	5kg/ha	ADHJ

8	AHDB 9821	Not for disclosure	1.25L/ha	AC

Application details

	A	B	C	D	E	F	G	H	I	J	K
Application date	03/11/22	07/11/22	08/11/22	10/11/22	11/11/22	14/11/22	15/11/22	17/11/22	21/11/22	24/11/22	28/11/22
Treatments	2-8	5, 6	8	2, 3, 4, 5, 7	6	5	6	2, 3, 4, 5, 7	5	2, 3, 4, 5, 7	5
Time of day	12:00-15:00	10:00-15:10	14:10-14:30	09:40-10:30	14:10-14:30	09:25-09:35	14:15-14:30	12:00-14:00	10:00-10:15	10:25-11:15	12:00-12:15
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	Flower bud to open flower
Crop height (cm)											
Crop coverage (%)											
Application Method	spay	spay	spay	spay	spay	spay	spay	spay	spay	spay	spay
Application Placement	Foliar	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)	Oxford Precision sprayer (knapsack)
Nozzle pressure	2-bar	2-bar	2-bar	2-bar	2-bar	2-bar	2-bar	2-bar	2-bar	2-bar	2-bar
Nozzle type	Flat fan	Flat fan	Flat fan	Flat fan	Flat fan	Flat fan	Flat fan	Flat fan	Flat fan	Flat fan	Flat fan
Nozzle size	02F110	02F110	02F110	02F110	02F110	02F110	02F110	02F110	02F110	02F110	02F110
Application water volume/ha	600	600	600	600	600	600	600	600	600	600	600
Compartment 4: Ambient temperature of air - shade (°C)	15.7	16.1	18.4	17.7	22.5	17.9	19.8	14.8	18.6	18.8	23.5
Compartment 5: Ambient temperature of air - shade (°C)	15.7	16.3	18.8	17.3	21.6	17.2	19.3	14.9	17.3	17.9	23.7
Compartment 4: Ambient relative humidity (%)	68.6	91.6	74.6	67.4	57.9	75.2	74.4	82.3	60.0	63.5	56.0
Compartment 5: Ambient relative	68.6	87.6	61.7	71.1	66.8	72.7	77.1	78.7	58.8	66.7	58.6

humidity (%)											
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	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	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	n/a
Wetness of soil - 2-5 cm	damp	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	n/a

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

Common name	Scientific Name	EPPO Code	Infestation level at release (Mean number of thrips per plant)	Infestation level at end of assessment period (Mean number of thrips per plant)
Onion thrips	*Thrips tabaci*	THRITB	10 (10 adults, 0 larvae)	10.29 (8.79 adults, 1.50 larvae)

Assessment details

Prior to the first spray application of treatments and release of thrips, spray coverage was evaluated using water-sensitive papers which were attached to a representative sample of upper canopy, middle canopy, and lower canopy leaves of chrysanthemum plants. Water was then applied to the plant at a rate of 600L/ha using the same equipment used for all subsequent treatment applications in this trial. Water-sensitive papers were then assessed visually to evaluate droplet deposition.

Forty adult female onion thrips reared in the laboratory at ADAS Boxworth were then added to each plot (four pot chrysanthemum plants in a thrips-proof cage) two weeks prior to the first treatment applications. Once consistent evidence of thrips leaf damage was seen in each plot (2-weeks following introduction), treatment applications were initiated. Treatments were applied over a 26-day period at manufacturer recommended rates, frequency, and intervals.

Assessments were undertaken prior to infestation, prior to the first treatment and six, 13, 20, and 27 days following the first treatment applications. On each assessment date five assessments were undertaken. Firstly, the number of (1) leaves and (2) flowers were counted on each plant on which any thrips damage was present (incidence of damage). Secondly the percentage total (1) leaf and (2) flower area damaged by thrips was estimated across each plot (estimate of the four plants). Finally, during the first assessment, two leaves on each plant (one at the base of each plant and one in the upper canopy) were marked and at each assessment the number of thrips adults and larvae on both upper and lower surfaces of these leaves were counted on each plant.

A final thrips count assessment was undertaken 28 days after the first treatment application. During this assessment, for each plant, all the flowers were tapped vigorously out over a white tray and the number of onion thrips adults and larvae recorded. The base of each stem was cut and all chrysanthemum leaf material per plant was also tapped out over a white tray and the number of onion thrips adults and larvae falling to the tray recorded. Following completion of flower and leaf thrips counts, plants were discarded. Counts of thrips adults and larvae in flowers and on leaves were thus recorded for each plant in the trial.

Evaluation date	Evaluation Timing (DA)*	Crop Growth Stage (BBCH)	Evaluation type (efficacy, phytotoxicity)	Assessment
18/10/2022	-16	Bud	Efficacy and phytotoxicity	**Pre-infestation assessment:** (1) Count of leaves with thrips damage (incidence) (2) Percentage of total leaf area damaged, (3) Count of flowers with thrips damage (4) Percentage flower damage (5) number of thrips on the upper and lower surface of the two marked leaves on each plant per plot.
02/11/2022	-1	Bud	Efficacy and phytotoxicity	**Pre-treatment assessment:** (1) Count of leaves with thrips damage (incidence) (2) Percentage of total leaf area damaged, (3) Count of flowers with thrips damage (4) Percentage flower damage (5) number of thrips on the upper and lower surface of the two marked leaves on each plant per plot.
09/11/2022	6	Bud	Efficacy and phytotoxicity	(1) Count of leaves with thrips damage (incidence) (2) Percentage of total leaf area damaged, (3) Count of flowers with thrips damage (4) Percentage flower damage (5) number of thrips on the upper and lower surface of the two marked leaves on each plant per plot.
16/11/2022	13	Bud	Efficacy and phytotoxicity	(1) Count of leaves with thrips damage (incidence) (2) Percentage of total leaf area damaged, (3) Count of flowers with thrips damage (4) Percentage flower damage (5) number of thrips on the upper and lower surface of the two marked leaves on each plant per plot.
23/11/2022	20	Flowering	Efficacy and phytotoxicity	(1) Count of leaves with thrips damage (incidence) (2) Percentage of total leaf area damaged, (3) Count of flowers with thrips damage (4) Percentage flower damage (5) number of thrips on the upper and lower surface of the two marked leaves on each plant per plot.
30/11/2022	27	Flowering	Efficacy and phytotoxicity	(1) Count of leaves with thrips damage (incidence) (2) Percentage of total leaf area damaged, (3) Count of flowers with thrips damage (4) Percentage flower damage (5) number of thrips on the upper and lower surface of the two marked leaves on each plant per plot (6) Destructive count of thrips larvae and adults on pot mums. For each plant, flowers and leaves were tapped out and thrips larvae and adults counted.

* DA – days after application

Statistical analysis

The data were analysed using an Analysis of Variance (ANOVA) approach followed by Duncan's Multiple Range post-hoc testing. Angular transformation was applied to percentage data (percentage leaf and flower area damaged). Abbot's formula was used to calculate percentage reduction in numbers of onion thrips, percentage flower/leaf area damaged, and the numbers of leaves/flowers with thrips damage present. All data was analysed using Genstat 21st Edition by the ADAS statistician, Chris Dyer.

Results

Spray coverage

Spray coverage was found to be good on the upper surface of upper, middle, and lower leaves (appendix figure 5). Little or no spray however was evident on the lower leaf surface on upper, middle, or lower leaves. This finding was consistent with spray coverage seen in SCEPTREplus WFT (*Frankliniella occidentalis*) trials (SP 5) on verbena in 2017 and 2018.

Number of onion thrips per plant (leaves plus flowers) at final assessment

Total onion thrips (adults plus larvae) per plant

At the final assessment on 01 Dec, 28 days after first treatment applications, a destructive count of total onion thrips in flowers and on leaves was undertaken, with total thrips per plant ranging from 3.04 - 13. 83 (Table 1). There were significant differences between treatments in total onion thrips adults and larvae per plant ($F(7,35)=4.64$, $P=<0.001$) and onion thrips adults per plant ($F(7,35)=6.26$, $P=<0.001$). For total onion thrips (adults plus larvae) per plant, treatment with AHDB 9728 and AHDB 9730 significantly reduced final mean total onion thrips (adults plus larvae) numbers relative to untreated controls, reducing populations by 70.4% and 67.6% respectively (Figure 1; Table 2). While Azatin, the industry standard positive control, notably lowered mean total onion thrips (adults plus larvae) counts, it did not significantly reduce mean total onion thrips at experimental conclusion relative to the untreated control ($P>0.05$). Aside from AHDB 9728 and AHDB 9730, no significant difference in concluding total thrips count was seen between all other treatments and the untreated control (Figure 1).

Onion thrips adults per plant

For the control of adult onion thrips alone, Azatin, AHDB 9728, AHDB 9730 and Eradicoat Max were all equally effective, significantly reducing adult thrips concluding population relative to untreated controls (means of 59.7%, 83.9%,73.9% and 55% population reductions respectively) (Figure 3; Table 2). All other treatments were ineffective compared with the untreated control ($P>0.05$).

Onion thrips larvae per plant

Numbers of larvae per plant were low at the final assessment, with a mean of only 1.5 per plant in the untreated controls. None of the treatments significantly reduced numbers.

Table 1: Mean numbers of live onion thrips per plant 28 days after application of the first treatments. Values sharing the same letters are not significantly different, those with different letters and shown on a blue background are significantly different.

Treatment	Adults per plant	Larvae per plant	Total thrips per plant
Untreated (Negative control)	**8.79 c**	1.50	**10.29 bcd**
Azatin (Positive control)	**3.54 ab**	1.04	**4.58 ab**
AHDB 9730	**2.29 ab**	1.04	**3.33 a**
AHDB 9728	**1.42 a**	1.63	**3.04 a**
Eradicoat® Max	**3.96 ab**	2.88	**6.83 abc**
AHDB 9768	**10.71 c**	3.13	**13.83 d**
AHDB 9729	**6.71 bc**	3.13	**9.83 bcd**
AHDB 9821	**10.54 c**	2.08	**12.63 cd**
ANOVA output			
F value	**6.26**	1.52	**4.64**
P value	**<0.001**	0.194	**<0.001**
d.f.	**7, 35**	7, 35	**7, 35**

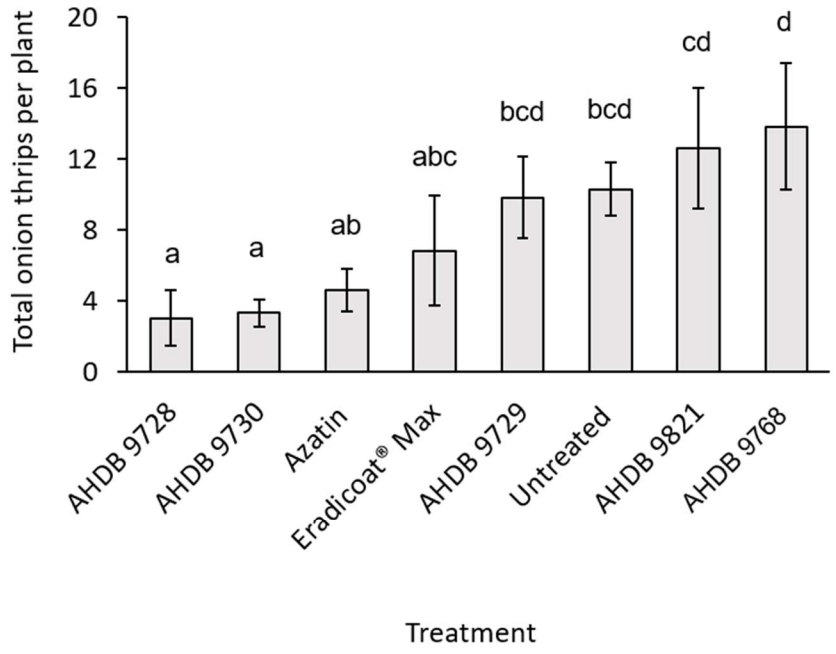


Figure 1: Mean numbers of total live onion thrips (adults plus larvae) per plant 28 days after application of the first treatments. Values sharing the same letters are not significantly different, those with different letters are significantly different (P<0.05).

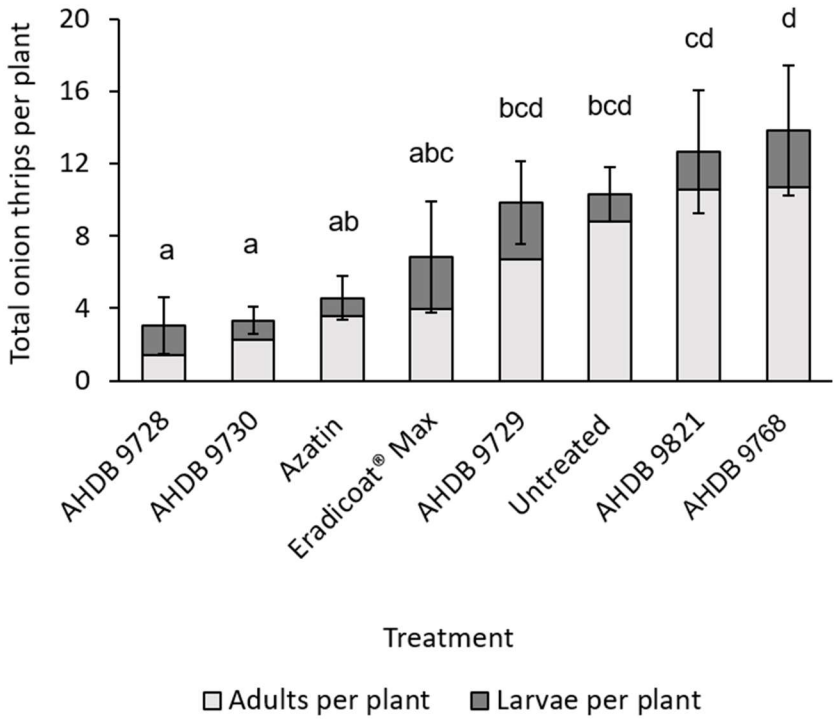


Figure 2: Mean numbers of total live adult and larvae onion thrips per plant 28 days after application of the first treatments. Values sharing the same letters are not significantly different, those with different letters are significantly different (P<0.05).

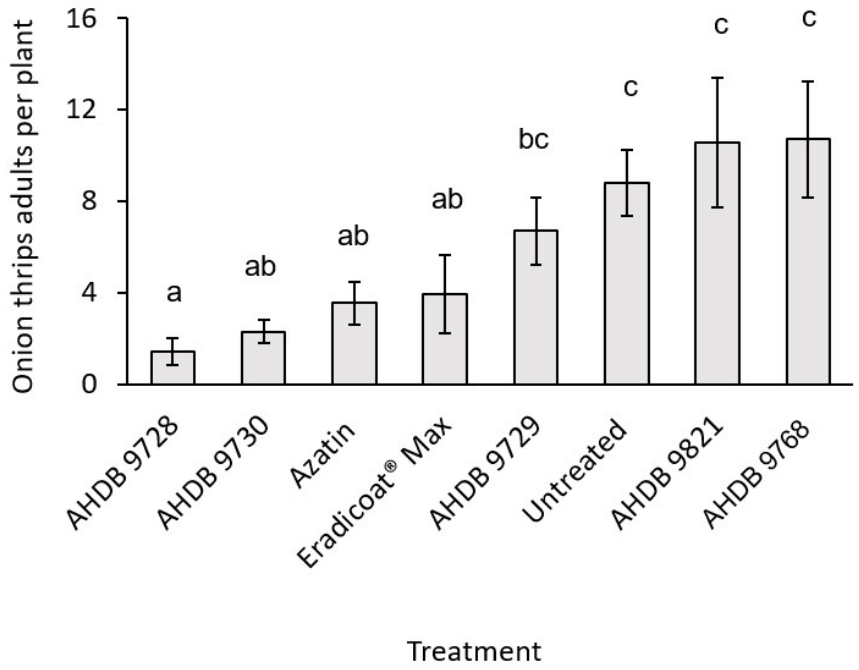


Figure 3: Mean numbers of live onion thrips adults per plant 28 days after application of the first treatments. Values sharing the same letters are not significantly different, those with different letters are significantly different (P<0.05).

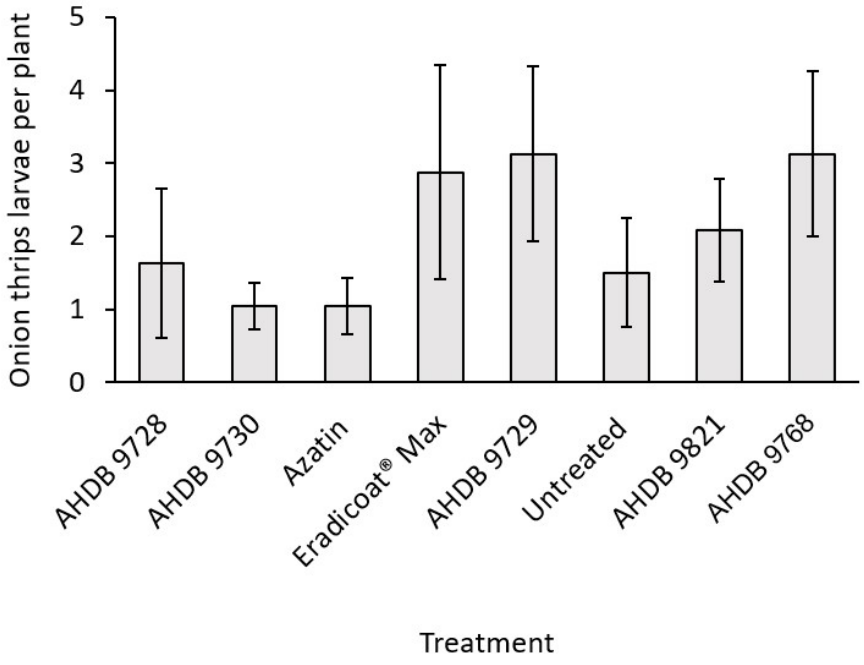


Figure 4: Mean numbers of live onion thrips larvae per plant 28 days after application of the first treatments. No significant difference was observed in larvae numbers on plants receiving different treatments (P>0.05).

Table 2: Percentage reduction in (a) mean thrips per plant, (b) mean adult thrips per plant, and (c) mean thrips larvae per plant relative to untreated control plants. Percentage changes for treatments which resulted in significantly different mean thrips per plant are highlighted in green ($P<0.05$).

Treatment	(a) Mean thrips per plant	Percentage reduction
Untreated	10.29	
Azatin	4.58	55.47
AHDB 9730	**3.33**	**67.62**
AHDB 9728	**3.04**	**70.44**
Eradicoat® Max	6.83	-
AHDB 9768	13.83	-
AHDB 9729	9.83	-
AHDB 9821	12.63	-
Treatment	**(b) Mean adults per plant**	**Percentage reduction**
Untreated	8.79	
Azatin	**3.54**	**59.71**
AHDB 9730	**2.29**	**73.93**
AHDB 9728	**1.42**	**83.88**
Eradicoat® Max	**3.96**	**54.98**
AHDB 9768	10.71	-
AHDB 9729	6.71	-
AHDB 9821	10.54	-
Treatment	**(c) Mean larvae per plant**	**Percentage reduction**
Untreated	1.50	
Azatin	1.04	-
AHDB 9730	1.04	-
AHDB 9728	1.63	-
Eradicoat® Max	2.88	-
AHDB 9768	3.13	-
AHDB 9729	3.13	-
AHDB 9821	2.08	-

Number of onion thrips in flowers at final assessment

Total onion thrips (adults plus larvae) per plant

There was a significant difference between treatments in the total onion thrips in flowers per plant (F(7,35)=3.12, P=0.001). While AHDB 9728, AHDB 9730, and Azatin notably reduced total thrips in flowers by 71.3%, 68.5%, and 64.6% respectively (Table 4), none of the seven evaluated treatments resulted in mean thrips (adults plus larvae) in flowers significantly different to untreated controls (Table 3; Figure 5; Table 4).

Onion thrips adults per plant

There was a significant difference between treatments in mean onion thrips adults in flowers per plant (F(7,35)=, P=0.011) Treatment with AHDB 9728, AHDB 9730, and Azatin significantly reduced mean adult thrips numbers in flowers per plant relative to untreated controls, reducing populations by 82.8%, 74.5%, and 66.9% respectively (Figure 7; Tables 3 and 4). None of the other treatments significantly reduced mean numbers of adult thrips in flowers.

Onion thrips larvae per plant

Most of the thrips found in the flowers were adults and there were no significant differences in the number of onion thrips larvae per plant (F(7,35), P=0.267) (Figure 8).

Table 3: Mean numbers of live onion thrips in flowers per plant 28 days after application of the first treatments. SIG. Values sharing the same letters are not significantly different, those with different letters are significantly different.

Treatment	Adults in flowers per plant	Larvae in flowers per plant	Total thrips in flowers per plant
Untreated (negative control)	**6.54 cd**	1.00	**7.54 ab**
Azatin (positive control)	**2.17 ab**	0.50	**2.67 a**
AHDB 9730	**1.67 ab**	0.71	**2.38 a**
AHDB 9728	**1.13 a**	1.04	**2.17 a**
Eradicoat Max	**3.13 abc**	2.04	**5.17 ab**
AHDB 9768	**8.00 cd**	2.70	**8.92 b**
AHDB 9729	**5.04 bcd**	2.29	**7.33 ab**
AHDB 9821	**7.96 d**	1.25	**9.21 b**
ANOVA output			
F value	**4.55**	1.33	**3.12**
P value	**0.001**	0.267	**0.011**
d.f.	**7, 35**	7,35	**7, 35**

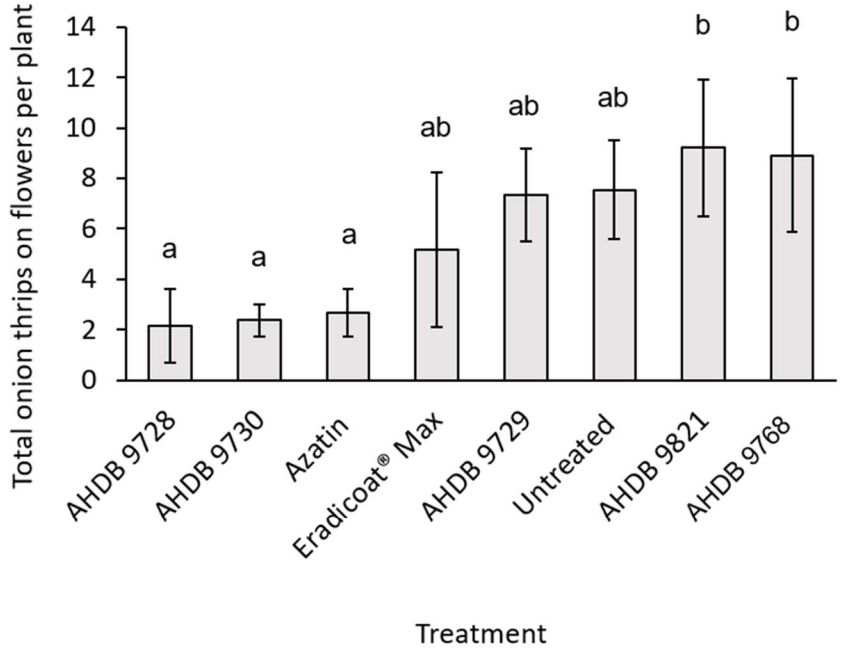


Figure 5: Mean numbers of total live onion thrips (adults and larvae) per plant in flowers 28 days after application of the first treatments. Values sharing the same letters are not significantly different, those with different letters are significantly different (P<0.05).

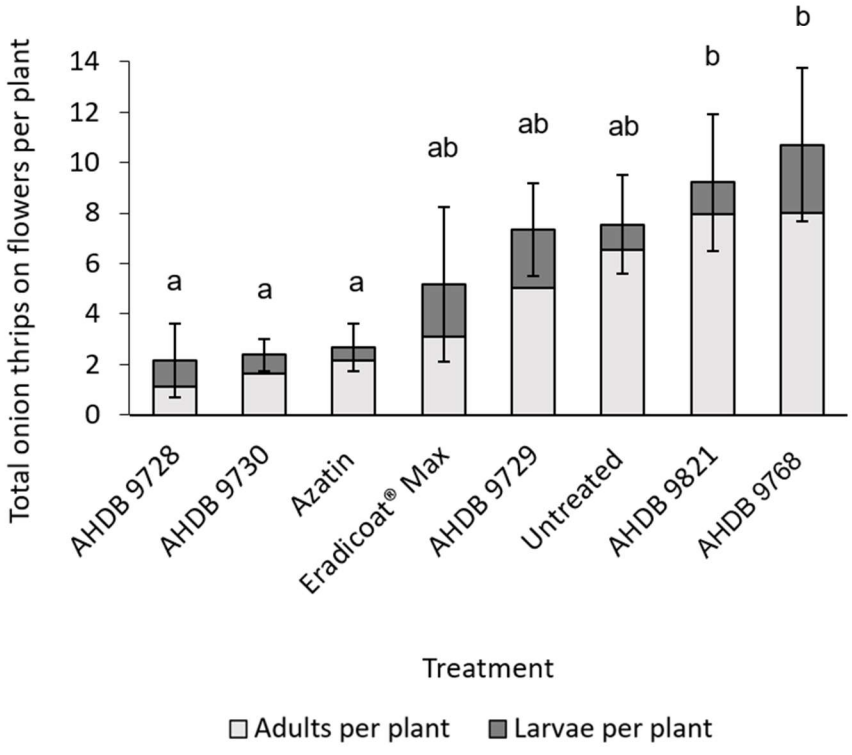


Figure 6: Mean numbers of total live adult and larvae onion thrips per plant in flowers 28 days after application of the first treatments. Values sharing the same letters are not significantly different, those with different letters are significantly different (P<0.05).

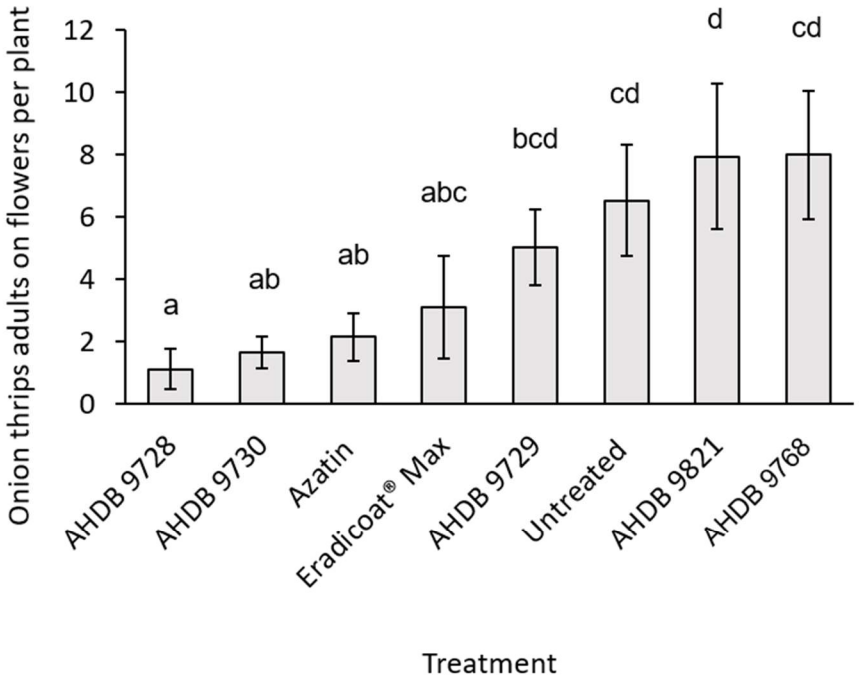


Figure 7: Mean numbers of live onion thrips adults per plant in flowers 28 days after application of the first treatments. Values sharing the same letters are not significantly different, those with different letters are significantly different (P<0.05).

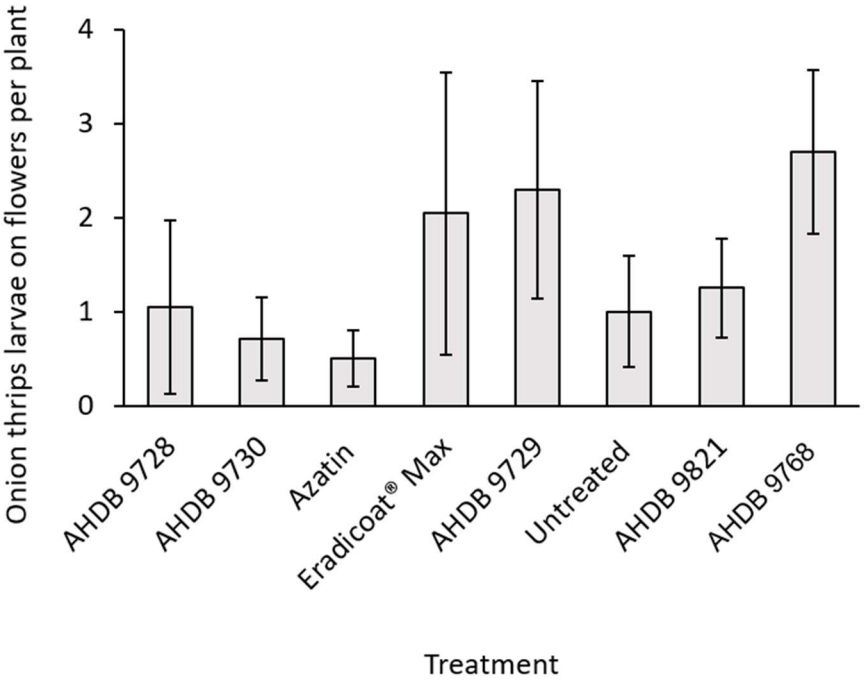


Figure 8: Mean numbers of live onion thrips larvae per plant in flowers 28 days after application of the first treatments. Analysis revealed no significant difference in mean number of live onion thrips larvae between treatments (P>0.05).

Table 4: Percentage reduction in (a) mean thrips in flowers per plant, (b) mean adult thrips in flowers per plant, and (c) mean thrips larvae in flowers per plant relative to untreated control plants. Percentage changes for treatments which resulted in significantly different mean thrips per plant are highlighted in green (P<0.05).

Treatment	(a) Mean thrips in flowers per plant	Percentage reduction
Untreated	7.54	
Azatin	2.67	-
AHDB 9730	2.38	-
AHDB 9728	2.17	-
Eradicoat® Max	5.17	-
AHDB 9768	8.92	-
AHDB 9729	7.33	-
AHDB 9821	9.21	-
Treatment	**(b) Mean adults in flowers per plant**	**Percentage reduction**
Untreated	6.54	
Azatin	**2.17**	**66.88**
AHDB 9730	**1.67**	**74.52**
AHDB 9728	**1.13**	**82.80**
Eradicoat® Max	3.13	-
AHDB 9768	6.67	-
AHDB 9729	5.04	-
AHDB 9821	7.96	-
Treatment	**(c) Mean larvae in flowers per plant**	**Percentage reduction**
Untreated	1.00	
Azatin	0.50	-
AHDB 9730	0.71	-
AHDB 9728	1.04	-
Eradicoat® Max	2.04	-
AHDB 9768	2.25	-
AHDB 9729	2.29	-
AHDB 9821	1.25	-

Number of onion thrips on leaves at final assessment

Total onion thrips (adults plus larvae) per plant

Across all treatments, the numbers of thrips on leaves were notably lower than in flowers – ranging from 0.88 – 4.92 (Table 5). There was a significant difference in the total onion thrips on flowers per plant ($F(7,35)=3.89$, $P=0.003$). However, the significant effect was an increase in numbers of thrips treated with AHDB 9768 compared with the untreated control, rather than any reductions in thrips numbers Tables 5 & 6; Figure 9). None of the treatments significantly reduced numbers of total onion thrips on leaves.

Onion thrips adults per plant

None of the treatments significantly reduced mean numbers of thrips adults per plant on leaves (Tables 5 & 6; Figure 11).

Onion thrips larvae per plant

Mean numbers of larvae per plant on leaves were very low; below one per leaf in most treatments including the untreated control. No significant difference was seen between treatments in the mean number of onion thrips larvae on leaves per plant ($F(7,35)=1.12$, $P=0.373$) (Table 5; Figure 12).

Table 5: Mean numbers of live onion thrips in flowers per plant 28 days after application of the first treatments. SIG. Values sharing the same letters are not significantly different, those with different letters are significantly different ($P<0.05$).

Treatment	Adults on leaves per plant	Larvae on leaves per plant	Thrips on leaves per plant
Untreated (negative control)	**2.25 abc**	0.50	**2.75 ab**
Azatin (positive control)	**1.38 ab**	0.54	**1.92 ab**
AHDB 9730	**0.63 ab**	0.33	**0.96 a**
AHDB 9728	**0.29 a**	0.58	**0.88 a**
Eradicoat Max	**0.83 ab**	0.83	**1.67 ab**
AHDB 9768	**4.85 c**	1.05	**4.92 c**
AHDB 9729	**1.67 ab**	0.83	**2.50 ab**
AHDB 9821	**2.58 bc**	0.83	**3.42 bc**
ANOVA output			
F value	**3.72**	1.12	**3.89**
P value	**0.004**	0.373	**0.003**
d.f.	**7, 35**	7, 35	**7, 35**

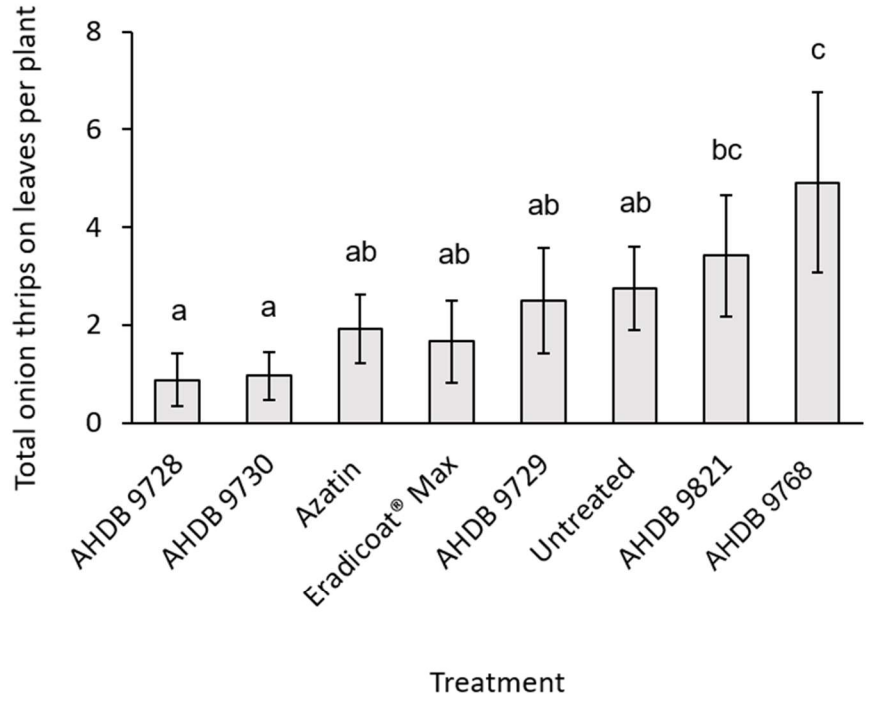


Figure 9: Mean numbers of total live onion thrips (adults and larvae) per plant on leaves 28 days after application of the first treatments. Values sharing the same letters are not significantly different, those with different letters are significantly different.

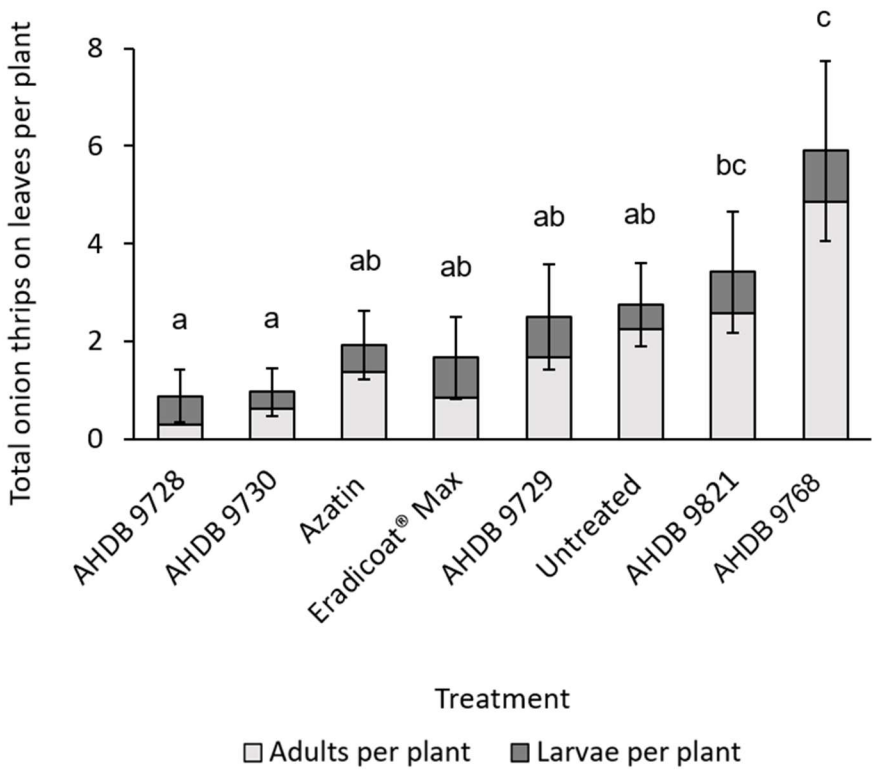


Figure 10: Mean numbers of total live adult and larvae onion thrips per plant on leaves 28 days after application of the first treatments. Values sharing the same letters are not significantly different, those with different letters are significantly different.

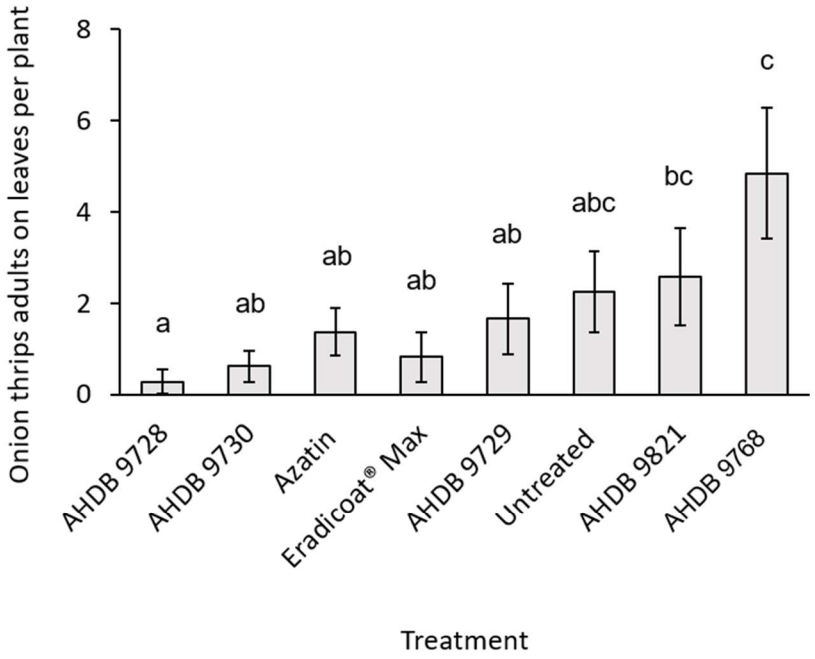


Figure 11: Mean numbers of live onion thrips adults per plant on leaves 28 days after application of the first treatments. Values sharing the same letters are not significantly different, those with different letters are significantly different.

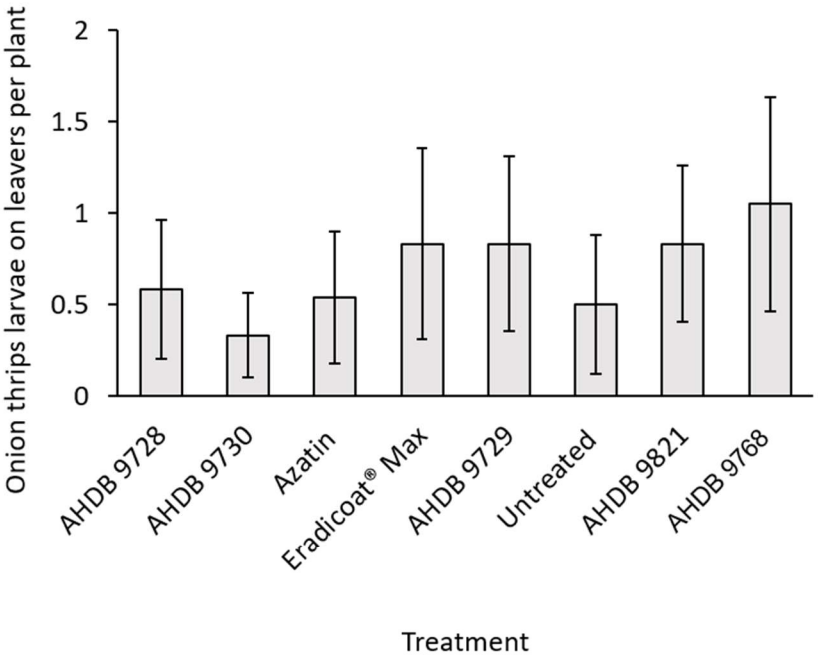


Figure 12: Mean numbers of live onion thrips larvae per plant on leaves 28 days after application of the first treatments. No significant difference was seen in the numbers of thrips larvae between plants receiving different treatments (P>0.05).

Table 6: Percentage reduction in (a) mean total thrips (adults plus larvae) on leaves per plant, (b) mean adult thrips on leaves per plant, and (c) mean thrips larvae on leaves per plant relative to untreated control plants. No treatments resulted in significantly lower mean thrips per plant.

Treatment	(a) Mean thrips on leaves per plant	Percentage reduction
Untreated	2.75	
Azatin	1.92	-
AHDB 9730	0.96	-
AHDB 9728	0.88	-
Eradicoat® Max	1.67	-
AHDB 9768	**4.92**	**-78.80**
AHDB 9729	2.50	-
AHDB 9821	3.42	-
Treatment	**(b) Mean adults on leaves per plant**	**Percentage reduction**
Untreated	2.25	
Azatin	1.38	-
AHDB 9730	0.63	-
AHDB 9728	0.29	-
Eradicoat® Max	0.83	-
AHDB 9768	4.04	-
AHDB 9729	1.67	-
AHDB 9821	2.58	-
Treatment	**(c) Mean larvae on leaves per plant**	**Percentage reduction**
Untreated	0.5	
Azatin	0.54	-
AHDB 9730	0.33	-
AHDB 9728	0.58	-
Eradicoat® Max	0.83	-
AHDB 9768	0.88	-
AHDB 9729	0.83	-
AHDB 9821	0.83	-

Incidence of leaf damage

On 18 October, prior to infestation of the plants, no leaves with thrips damage were identified across all treatments (Table 7). On 2 November, one day before the first treatment (12-days post infestation with onion thrips), the numbers of leaves with evident thrips damaged ranged from 2.96-5.38, but there were no significant difference in the numbers of leaves with thrips damage present between treatments (P>0.05) (Table 7; Figure 13).

On 9 November, 6-days following first treatment applications, thrips damage had increased markedly, with the number of leaves with thrips damage evident ranging from 9.88-15.13 across all treatments. However, there were no significant difference in the number of leaves with thrips damage between treatments on this date (F(7,35)=0.52, P=0.816). The average number of leaves with thrips damage continued to increase markedly on subsequent assessments, but there were no significant differences between treatments until the final assessment on 30 November.,

On 30 November, only AHDB 9728 led to significantly fewer mean leaves damaged per plant (17.33) than untreated controls (33.38), a 48.1% reduction (Table 8).

Table 7: Mean numbers of leaves per plant with onion thrips damage pre-treatment, -1-, 6-, 13-, 20-, and 27-days after application of the first treatments. Significant difference in number of leaves with thrips damage on 30 November only (P=0.004). Values sharing the same letters are not significantly different, those with different letters are significantly different (P<0.05).

Treatment	Average number of leaves with thrips damage					
	18 Oct (pre-infestation)	**02 Nov (-1 day)**	**09 Nov (day 6)**	**16 Nov (day 13)**	**23 Nov (day 20)**	**30 Nov (day 27)**
Untreated	0	4.67	13.17	25.79	30.96	**33.38 bc**
Azatin	0	4.17	9.88	19.71	22.63	**26.33 ab**
AHDB 9730	0	2.96	10.96	19.88	23.92	**21.17 ab**
AHDB 9728	0	3.67	10.35	14.92	19.83	**17.33 a**
Eradicoat® Max	0	5.17	12.50	21.71	21.08	**21.25 ab**
AHDB 9768	0	5.00	15.13	34.96	40.94	**46.08 c**
AHDB 9729	0	5.08	14.04	28.25	33.46	**32.29 abc**
AHDB 9821	0	5.38	12.33	22.58	26.29	**29.42 ab**
ANOVA output						
F value	n/a	0.45	0.52	2.10	2.21	**3.78**
P value	n/a	0.865	0.816	0.070	0.057	**0.004**
d.f.	n/a	7, 35	7, 35	7, 35	7, 35	**7, 35**

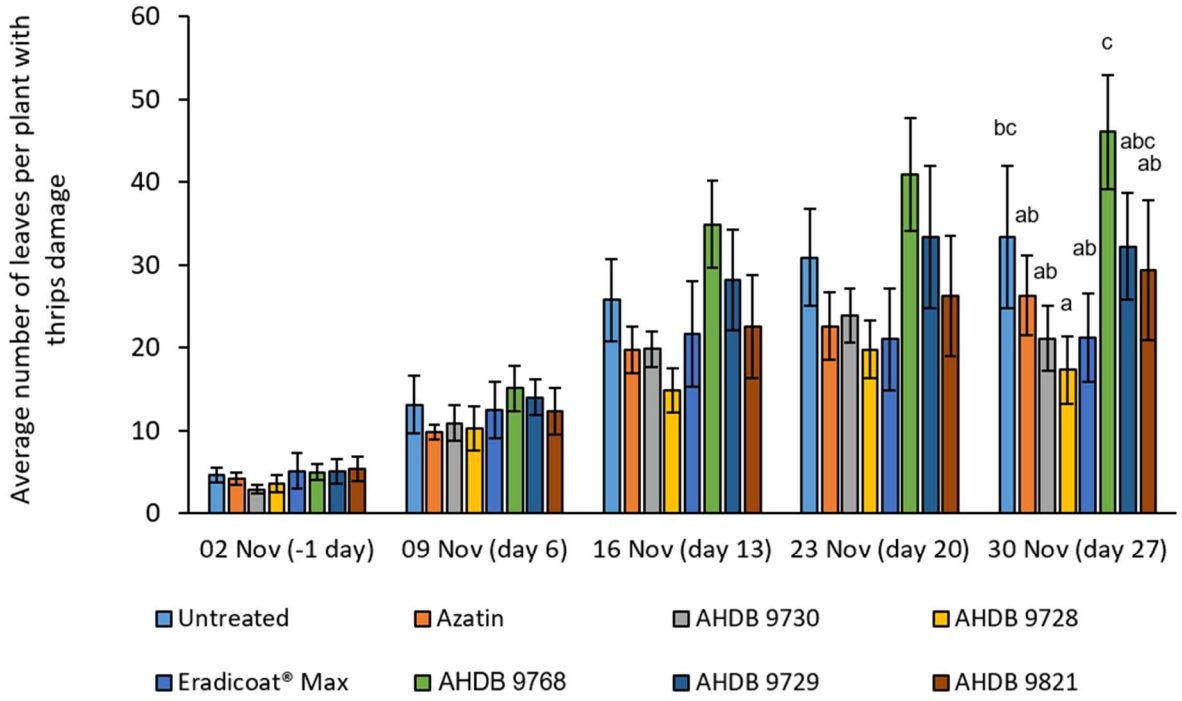


Figure 13: Mean numbers of leaves per plant with onion thrips damage pre-treatment, -1-, 6-, 13-, 20-, and 27-days after application of the first treatments. Values sharing the same letters are not significantly different, those with different letters are significantly different (P<0.05).

Table 8: Mean number of leaves with onion thrips damage on each assessment date and percentage reduction in the mean number of leaves with thrips damage relative to untreated control plants. Percentage changes for treatments which resulted in significantly different mean thrips per plant relative to untreated control are highlighted in green (P<0.05).

Treatment	Mean number of leaves with thrips damage				
	02-Nov	09-Nov	16-Nov	23-Nov	30-Nov
Untreated	4.67	13.17	25.79	30.96	33.38
Azatin	4.17	9.88	19.71	22.62	26.33
AHDB 9730	2.96	10.96	19.88	23.92	21.17
AHDB 9728	3.67	10.35	14.92	19.83	**17.33**
Eradicoat® Max	5.17	12.50	21.71	21.08	21.25
AHDB 9768	5.00	15.12	34.96	40.94	46.08
AHDB 9729	5.08	14.04	28.25	33.46	32.29
AHDB 9821	5.38	12.33	22.58	26.29	29.42
Treatment	**Percentage reduction in leaves with thrips damage**				
	02-Nov	**09-Nov**	**16-Nov**	**23-Nov**	**30-Nov**
Untreated					
Azatin	-	-	-	-	-
AHDB 9730	-	-	-	-	-
AHDB 9728	-	-	-	-	**48.08**
Eradicoat® Max	-	-	-	-	-
AHDB 9768	-	-	-	-	-
AHDB 9729	-	-	-	-	-
AHDB 9821	-	-	-	-	-

Percentage leaf area damaged

Prior to onion thrips infestation of the plants on 18 October, no thrips damage on leaves was identified across all treatments. On 2 November, one day before the first treatment (12-days post infestation with onion thrips), percentage leaf area with evident thrips damaged ranged from 0.30-0.72%, with no significant difference in percentage leaf area with thrips damage between treatments (P>0.05) (Table 9; Figure 14).

Percentage damaged leaf area increased on subsequent assessment dates, with values ranging from 3.67-5.75% at the final assessment on 30 November (Table 10). However, none of the treatments led to a significant reduction in percentage leaf area damaged on any date (Tables 9 &10).

Table 9: Mean percentage total leaf area damaged by onion thrips pre-treatment, -1, 6, 13, 20, and 27 days after application of the first treatments. Percentage data was transformed using an angular transformation and analysed using ANOVA. Significant difference in percentage total leaf area with thrips damage between treatments on 16 November and 30 November (P=0.045 and P=0.042), but no significant differences between treatments and untreated control. Values sharing the same letters are not significantly different, those with different letters are significantly different (P<0.05).

Treatment	Percentage of total leaf area with thrips damage					
	18 Oct (pre-infestation)	**02 Nov (-1 day)**	**09 Nov (day 6)**	**16 Nov (day 13)**	**23 Nov (day 20)**	**30 Nov (day 27)**
Untreated	0	0.35	1.25	**2.92 ab**	4.83	**5.50 a**
Azatin	0	0.32	1.00	**2.00 a**	3.58	**4.67 a**
AHDB 9730	0	0.30	1.08	**2.25 a**	3.67	**3.67 a**
AHDB 9728	0	0.40	1.08	**1.67 a**	2.92	**5.25 a**
Eradicoat® Max	0	0.50	1.17	**2.33 a**	3.92	**3.67 a**
AHDB 9768	0	0.72	1.58	**4.33 b**	6.58	**8.17 b**
AHDB 9729	0	0.38	1.25	**3.33 ab**	5.67	**5.75 ab**
AHDB 9821	0	0.47	1.17	**2.50 a**	4.08	**5.25 a**
ANOVA output						
F value	n/a	1.83	0.50	**2.34**	1.76	**2.39**
P value	n/a	0.113	0.831	**0.045**	0.128	**0.042**
d.f.	n/a	7, 35	7, 35	**7, 35**	7, 35	**7, 35**

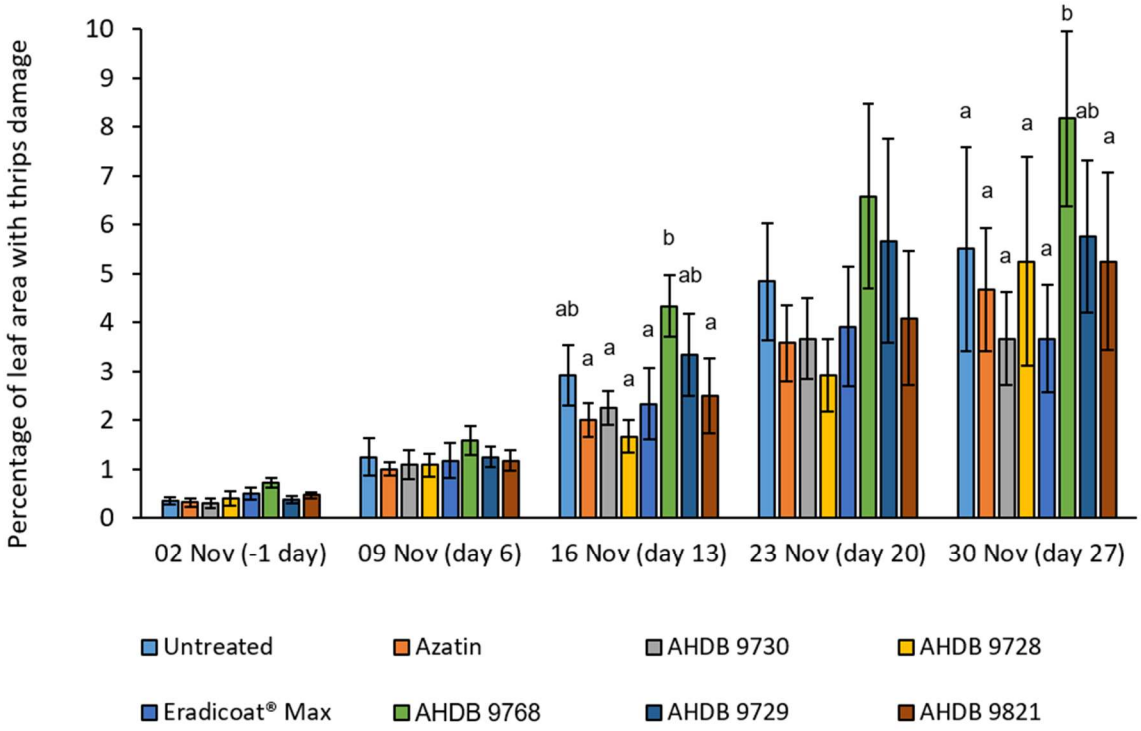


Figure 14: Mean percentage total leaf area damaged by onion thrips pre-treatment, -1-, 6-, 13-, 20-, and 27-days after application of the first treatments. Values sharing the same letters are not significantly different, those with different letters are significantly different ($P<0.05$).

Table 10: Back transformed mean percentage of chrysanthemum leaf area with onion thrips damage on each assessment date and percentage reduction in the mean percentage leaf area with thrips damage relative to untreated control plants. No treatments resulted in significantly decreased mean percentage leaf area damaged relative to untreated control.

Treatment	Back-transformed mean percentage leaf damage				
	02-Nov	09-Nov	16-Nov	23-Nov	30-Nov
Untreated	8.79	1.13	2.74	4.49	4.57
Azatin	3.54	0.98	1.93	3.40	4.30
AHDB 9730	2.29	0.98	2.19	3.41	3.36
AHDB 9728	1.42	1.02	1.57	2.71	4.37
Eradicoat® Max	3.96	1.04	2.05	3.45	3.27
AHDB 9768	10.71	1.53	4.23	5.99	**7.68**
AHDB 9729	6.71	1.20	3.09	4.88	5.21
AHDB 9821	10.54	1.12	2.25	3.59	4.59

Treatment	Percentage reduction in percentage leaf damage area				
	02-Nov	09-Nov	16-Nov	23-Nov	30-Nov
Untreated					
Azatin	-	-	-	-	-
AHDB 9730	-	-	-	-	-
AHDB 9728	-	-	-	-	-
Eradicoat® Max	-	-	-	-	-
AHDB 9768	-	-	-	-	**-67.97**
AHDB 9729	-	-	-	-	--
AHDB 9821	-	-	-	-	-

Incidence of flowers damaged.

Owing to this trial being designed to closely match a commercial 10-week pot chrysanthemum production system, at onion thrips infestation and early assessments, pot chrysanthemums were still at the bud stage and flower damage assessments could not be undertaken. Flowers were open during only the final two assessments on 23 and 30 November thus flower damage assessment could only be undertaken on these dates.

There were no significant differences in numbers of flowers with thrips damage between treatments on any date (Tables 11&12; Figure 15).

Table 11: Mean numbers of chrysanthemum flowers per plant with onion thrips damage pre-treatment, -1, 6, 13, 20, and 27 days after application of the first treatments. Flower buds were found open only from day 20 onwards. No significant difference in the average number of flowers with thrips damage on 23 or 30 November (P>0.05).

Treatment	Average number of flowers with thrips damage					
	18 Oct (pre-infestation)	02 Nov (-1 day)	09 Nov (day 6)	16 Nov (day 13)	23 Nov (day 20)	30 Nov (day 27)
Untreated	n/a	n/a	n/a	n/a	0.63	5.58
Azatin	n/a	n/a	n/a	n/a	0.71	5.13
AHDB 9730	n/a	n/a	n/a	n/a	0.46	5.38
AHDB 9728	n/a	n/a	n/a	n/a	0.33	3.38
Eradicoat® Max	n/a	n/a	n/a	n/a	0.42	5.42
AHDB 9768	n/a	n/a	n/a	n/a	0.29	4.29
AHDB 9729	n/a	n/a	n/a	n/a	0.13	5.08
AHDB 9821	n/a	n/a	n/a	n/a	1.13	5.17
ANOVA output						
F value	n/a	n/a	n/a	n/a	1.03	0.72
P value	n/a	n/a	n/a	n/a	0.429	0.657
d.f.	n/a	n/a	n/a	n/a	7, 35	7, 35

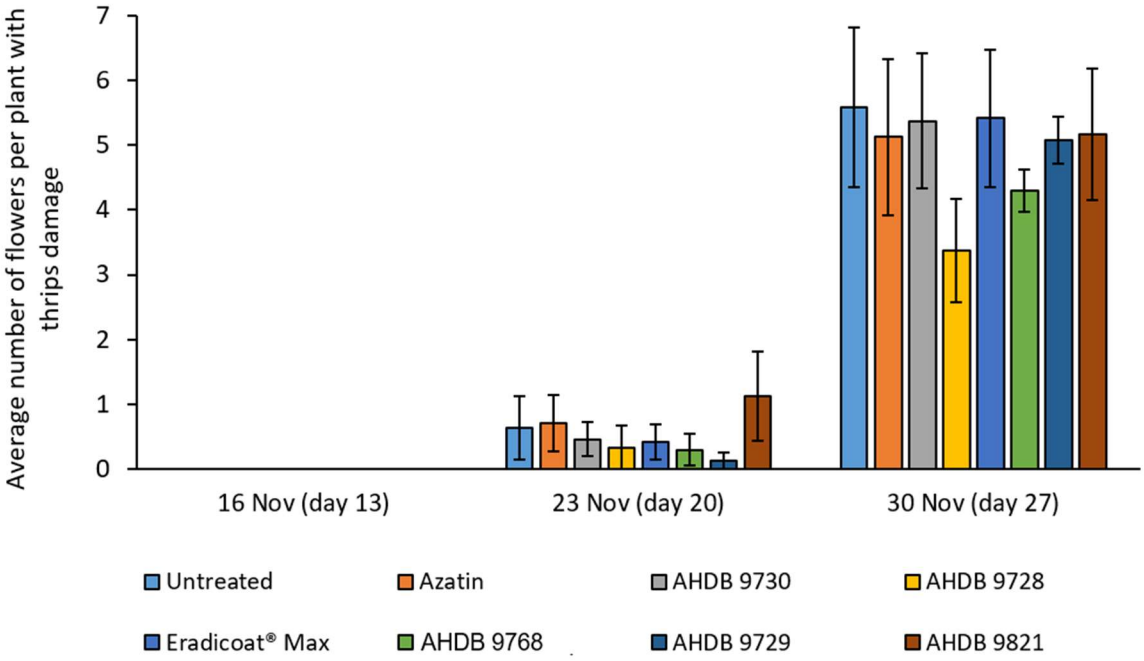


Figure 15: Mean numbers of chrysanthemum flowers per plant with onion thrips damage pre-treatment, -1-, 6-, 13-, 20-, and 27-days after application of the first treatments. No significant difference in number of flowers per plant with thrips damage across all treatments and assessment dates (P>0.05).

Table 12: Mean number of Chrysanthemum flowers per plant with onion thrips damage on each assessment date and percentage reduction in the mean number of leaves with thrips damage relative to untreated control plants. No significant difference in number of flowers per plant with thrips damage across all treatments and assessment dates (P>0.05).

Treatment	Mean number of flowers with thrips damage	
	23-Nov	30-Nov
Untreated	0.63	5.58
Azatin	0.71	5.13
AHDB 9730	0.46	5.38
AHDB 9728	0.33	3.38
Eradicoat® Max	0.42	5.42
AHDB 9768	0.29	4.29
AHDB 9729	0.13	5.08
AHDB 9821	1.13	5.17
Treatment	Percentage reduction in number of flowers with thrips damage	
	23-Nov	30-Nov
Untreated		
Azatin	-	-
AHDB 9730	-	-
AHDB 9728	-	-
Eradicoat® Max	-	-
AHDB 9768	-	-
AHDB 9729	-	-
AHDB 9821	-	-

Percentage of flower area damaged

On 23 November, three weeks after the first treatment applications, the average flower area with onion thrips damage across all treatments ranged from 0.17-2.75%, with no significant difference in the average number of flowers damaged per plant on 23 Nov ($F(7,35)=0.93$, $P=0.499$) (Table 13; Figure 16).

At the final assessment on 30 November, four-weeks after the first treatment applications, notably more percentage flower area had thrips damage, ranging from 9.00-15.67% across all treatments. There were no significant difference in the average number of flowers with thrips damage between treatments ($F(7,35)=1.19$ $P=0.333$) (Table 13; Figure 16).

Table 13: Mean percentage total flower area damaged by onion thrips pre-treatment, -1-, 6-, 13-, 20-, and 27-days after application of the first treatments. Flower buds were found open only from day 20 onwards Percentage data was transformed using an angular transformation and analysed using ANOVA. No significant differences between treatments on 23 November or 30 November ($P>0.05$).

Treatment	Percentage of total flower area with thrips damage					
	18 Oct (pre-infestation)	02 Nov (-1 day)	09 Nov (day 6)	16 Nov (day 13)	23 Nov (day 20)	30 Nov (day 27)
Untreated	n/a	n/a	n/a	n/a	1.83	12.17
Azatin	n/a	n/a	n/a	n/a	1.33	13.50
AHDB 9730	n/a	n/a	n/a	n/a	0.58	13.17
AHDB 9728	n/a	n/a	n/a	n/a	0.83	9.00
Eradicoat® Max	n/a	n/a	n/a	n/a	0.67	11.33
AHDB 9768	n/a	n/a	n/a	n/a	0.58	15.67
AHDB 9729	n/a	n/a	n/a	n/a	0.17	13.67
AHDB 9821	n/a	n/a	n/a	n/a	2.75	13.6
ANOVA output						
F value	n/a	n/a	n/a	n/a	0.93	1.19
P value	n/a	n/a	n/a	n/a	0.499	0.333
d.f.	n/a	n/a	n/a	n/a	7, 35	7, 35

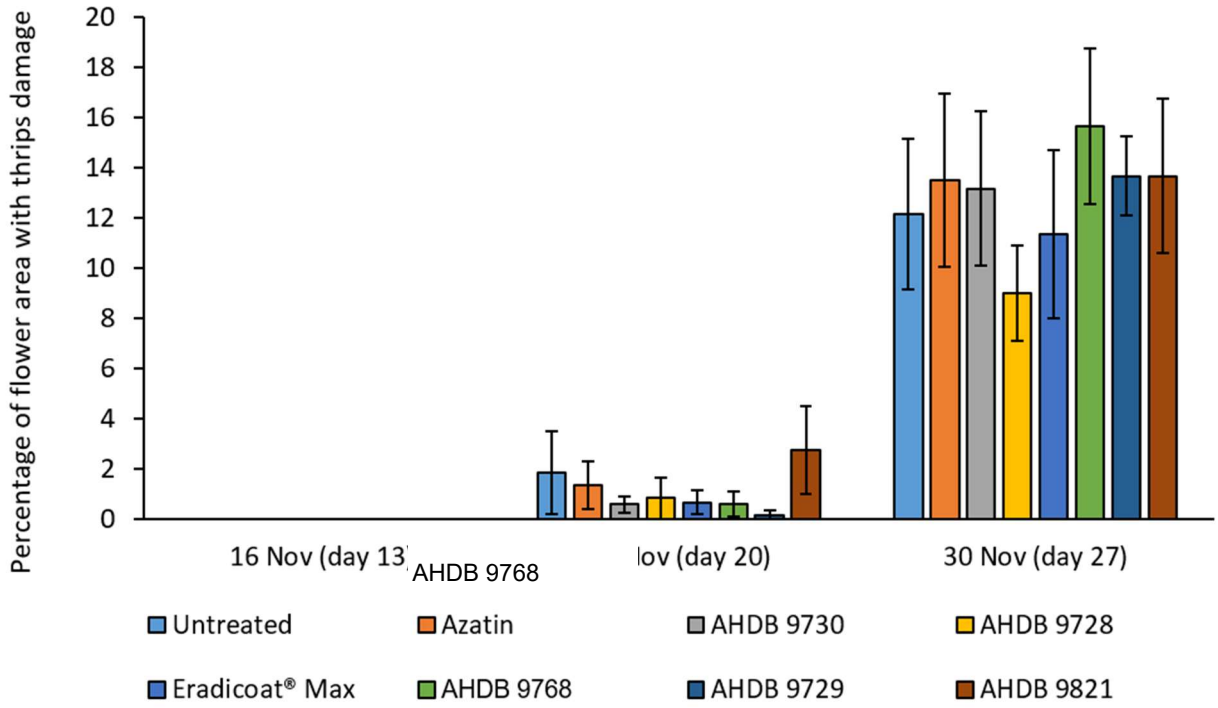


Figure 16: Mean percentage total flower area damaged by onion thrips pre-treatment, -1, 6, 13, 20, and 27 days after application of the first treatments. No significant differences between treatments across all assessment dates (P>0.05).

Table 14: Mean number of flowers per plant with onion thrips damage on each assessment date and percentage reduction in the mean number of leaves with thrips damage relative to untreated control plants. No significant differences between treatments on either date (P>0.05).

Treatment	Back-transformed mean percentage flower area with thrips damage	
	23-Nov	30-Nov
Untreated	0.49	11.34
Azatin	0.56	12.37
AHDB 9730	0.27	12.48
AHDB 9728	0.14	8.46
Eradicoat® Max	0.21	9.98
AHDB 9768	0.17	15.05
AHDB 9729	0.03	13.48
AHDB 9821	1.13	12.94

Treatment	Percentage reduction in mean percentage flower area with thrips damage	
	23-Nov	30-Nov
Untreated		
Azatin	-	-
AHDB 9730	-	-
AHDB 9728	-	-
Eradicoat® Max	-	-
AHDB 9768	-	-
AHDB 9729	-	-
AHDB 9821	-	-

Phytotoxicity

Prior to infestation of plants with onion thrips, to match commercial treatment of potted chrysanthemums, at 3-weeks old the plants were treated with a growth regulator on 20 October (B-NINE SG, Daminozide, MAPP 14434; kg product/ha: 1.8kg/ha, water volume: 600L/ha, g product/L: 3g/L). Following this application, on 02 November, phytotoxicity (bleaching of upper leaves, Figure 17) was noted in three plots.

Within the trial, no further phytotoxicity symptoms were recorded on any subsequent assessment dates following applications of the seven evaluated plant protection products.

Discussion

- Total thrips count assessments at experimental conclusion revealed that treatments AHDB 9728 and AHDB 9730 significantly reduced mean total onion thrips (adults plus larvae) numbers on chrysanthemum plants (leaves plus flowers), reducing numbers by 70.4% and 67.6% respectively. These treatments led to control comparable to Azatin (azadirachtin), the industry standard control which is approved with an on-label recommendation for the control of onion thrips (*Thrips tabaci*) and western flower thrips (*Frankliniella occidentalis*) on protected ornamentals under permanent protection (full enclosure).
- On the final assessment date, mean numbers of onion thrips adults per plant (leaves plus flowers) were significantly reduced by AHDB 9728, AHDB 9730, Azatin and Eradicoat Max. All these treatments were equally effective. Eradicoat Max is approved for use on all protected edible and non-edible crops, with a label recommendation for control of spider mites and whitefly.
- During the final thrips count assessment, most thrips adults and larvae were found in the chrysanthemum flowers (untreated control treatments average thrips: 7.54 in flowers, 2.75 on leaves). While *T. tabaci* is frequently discussed as predominantly damaging to leaf material including on chrysanthemums (Jandricic *et* al, 2020; Koppert, 2022) this finding highlights that *T. tabaci* is a potential pest of both leaves and flowers and may prefer flowers as a food source in some plant species. The variety of pot chrysanthemum used in this trial (Rainbow Circus) is very susceptible to western flower thrips damage on a commercial nursery (personal communication, Braime and Szejna, 2022) and was also susceptible to onion thrips damage in this experiment. Further work may therefore be warranted to assess the ornamental and cut flower crops and varieties on which onion thrips may be the most problematic.
- Very few onion thrips larvae had developed in flowers or on leaves by the end of the experiment. Across both glasshouse compartments, the average temperature during this trial was 17.8°C. In the literature, at a temperature of 17.5°C, onion thrips development from eggs to adulthood is estimated to take an average of 32.8 days while development from eggs to larvae is estimated to average 19.3 days (Burnstone, 2009). In this trial, there were 41 days from when thrips were added until their total population was counted, thus while there was sufficient time for larvae to arise, there was limited time for a second adult population to emerge – this is reflected in the trial results, with fewer concluding adults on control plants (8.79) relative to the 10 thrips per plant initially released.
- When onion thrips on leaves and in flowers were considered separately, mean numbers of adults in flowers were significantly reduced by Azatin, AHDB 9730 and AHDB 9728. Despite this, no significant reduction in incidence of flower damage or percentage flower area damaged. This demonstrated that reductions in mean thrips numbers in flowers to 1-2 adults per plant did not prevent flower damage.
- While no significant differences were seen in flower damage incidence and percentage flower area damaged between treatments, a trend was observed of lower numbers of flowers damaged and less flower area damaged on plants treated with AHDB 9728 relative to all other treatments.
- Significant differences between treatments in the incidence of leaves damaged by onion thrips was found only on the final trial assessment date (30 Nov), with AHDB 9728 significantly reducing leaves damaged by 48.1% relative to untreated control.
- The lack of significant differences seen in onion thrips induced flower damage between plants receiving different treatments may suggest that spray application of treatments struggled to control thrips once they had entered developing flower buds. It has long been understood that thrips display thigmotactic behavior, sheltering in tight crevices including flower buds, with such activity likely sheltering thrips from treatments.
- In this trial manufacturers of two products, AHDB 9729 and AHDB 9768, recommended application at high humidity levels to achieve maximum efficacy. Despite consistently high humidity inside the cages in both glasshouse compartments throughout the trial (>80% average percentage relative humidity on almost all dates, appendix figures 3

and 4), both AHDB 9768 and AHDB 9729 failed to significantly reduce concluding thrips numbers and thrips leaf/flower damage at all assessment dates relative to untreated control plant.

- In several instances AHDB 9768 was found to perform significantly worse in controlling thrips numbers and damage relative to untreated control. This finding however is likely a statistical or experimental anomaly, with no previous reports of negative effects of this treatment on plant defence against thrips pests, or positive effects of AHDB 9768 on thrips reproduction, survival, or damage.
- As this trial was undertaken from October to November 2022, temperatures during the trial period were likely lower than temperatures summer glasshouse and outdoor summer cut-flower crops are subject to – averaging 17.8°C across both glasshouse compartments for the duration of the trial (appendix figures 2 and 3). Significant evidence exists demonstrating the close link between onion thrips reproduction/development rates with temperature - with notably higher rates of both life history traits at elevated temperatures (Burnstone, 2009). It may therefore be valuable to repeat evaluation of more promising treatments in this trial under Spring and Summer conditions to confirm efficacy and phytotoxicity under a higher onion thrips pressure.
- Despite sunny conditions on many days throughout the trial, no phytotoxicity was observed following the application of trialled plant protection products. Conversely, some phytotoxicity was observed following the application of B-NINE SG, (daminozide, MAPP 14434) prior to thrips release and trial treatment applications (Appendix figure 6). No phytotoxicity issues are referenced on the B-NINE SG label, however advice is offered to spray in the late afternoon under cooler conditions.

Conclusions

- The results of this trial highlight two currently unavailable treatments, AHDB 9728 and AHDB 9730, which may be of value to growers for the control of onion thrips on protected ornamentals and cut flowers if they gain approval in the UK. Both performed similarly to the currently available product for thrips control, Azatin.
- The trial also highlighted that Eradicoat Max, currently approved for control of spider mite and whitefly on protected edible and non-edible crops, gave similar reduction of onion thrips adults as Azatin.
- Owing to the lack of difference seen in flower damage even when treatments reduced numbers of thrips, this trial highlights that it is paramount for growers of ornamental crops to not rely on plant protection products for control of onion thrips, but to use them as part of an IPM programme including the preventive use of biological control agents such as predatory mites and in the case of pot chrysanthemum, entomopathogenic nematodes. This will help to manage thrips populations before the buds and flowers open. Azatin, Eradicoat Max, AHDB 9728 and AHDB 9730 are compatible with beneficials used in IPM programmes.
- Despite six replicate blocks per treatment being undertaken, with four replicate plants per plot, large variation in thrips numbers and thrips damage was observed. Further trials to assess promising treatments, particularly AHDB 9728 and AHDB 9730, against onion thrips on other protected ornamental and cut flower crops are warranted to determine more precisely their efficacy in reducing thrips numbers and damage relative to existing controls e.g., Azatin.

Acknowledgements

With thanks to the AHDB for funding and supporting this project and for the kind contributions of products from manufactures: CertisBelchim, Oro Agri, Fargro, Russell IPM, and BASF.

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Appendix

a. Trial diary

Appendix Table 1: Trial Diary

Date	Comment
30/09/2022	Pot chrysanthemums collected from grower (2-weeks old).
18/10/2022	Pre-infestation assessment. No thrips damage or individuals were identified.
19/10/2022	Reduced number of chrysanthemum pots down to 4 in each cage Moved spare plants into bugdorms. Compressed the growing media of each of the pots before assessments to limit the amount lost when tapping off the plants.
20/10/2022	Applied B-nine SG growth regulator spray treatment to all pots and watered thoroughly before infestation the following day to avoid watering and disrupting the thrips.
21/10/2022	Completed thrips infestation. Pooted 20 adult thrips per tube. Placed 2 opened tubes onto the plant foliage in each of the cages.
02/11/2022	Completed -1 (pre-treatment) assessment.
03/11/2022	Completed spray with treatments 1-8.
07/11/2022	Completed treatments 5 and 6 sprays.
08/11/2022	Completed treatment 8 spray
09/11/2022	Completed 6-day assessment.
10/11/2022	Completed treatment sprays (2, 3, 4, 5, 7)
11/11/2022	Completed treatment 6 spray
14/11/2022	Completed treatment 5 spray
15/11/2022	Completed treatment 6 spray
16/11/2022	Completed 13-day assessment. Visibly more damage observed on untreated plots.
17/11/2022	Completed treatment sprays (2, 3, 4, 5, 7)
21/11/2022	Completed treatment 5 spray
23/11/2022	Completed 20-day assessment. No flowers had emerged yet in compartment 5 but some flowers had emerged in every plot in compartment 4. Lots of flower damage observed.
24/11/2022	Completed treatment sprays (2, 3, 4, 5, 7)
28/11/2022	Completed treatment 5 spray
30/11/2022	Completed 26-day assessment. 50% flower emergence in compartment 5 and 100% emergence in compartment 4.
01/12/2022	Completed full count of thrips per plant. Heads of flowers were tapped into a white tray to count numbers of adults and larvae just from flowers. Plants were then cut at the base and tapped onto the white tray to count numbers on the leaves. Plants were then immediately disposed of.

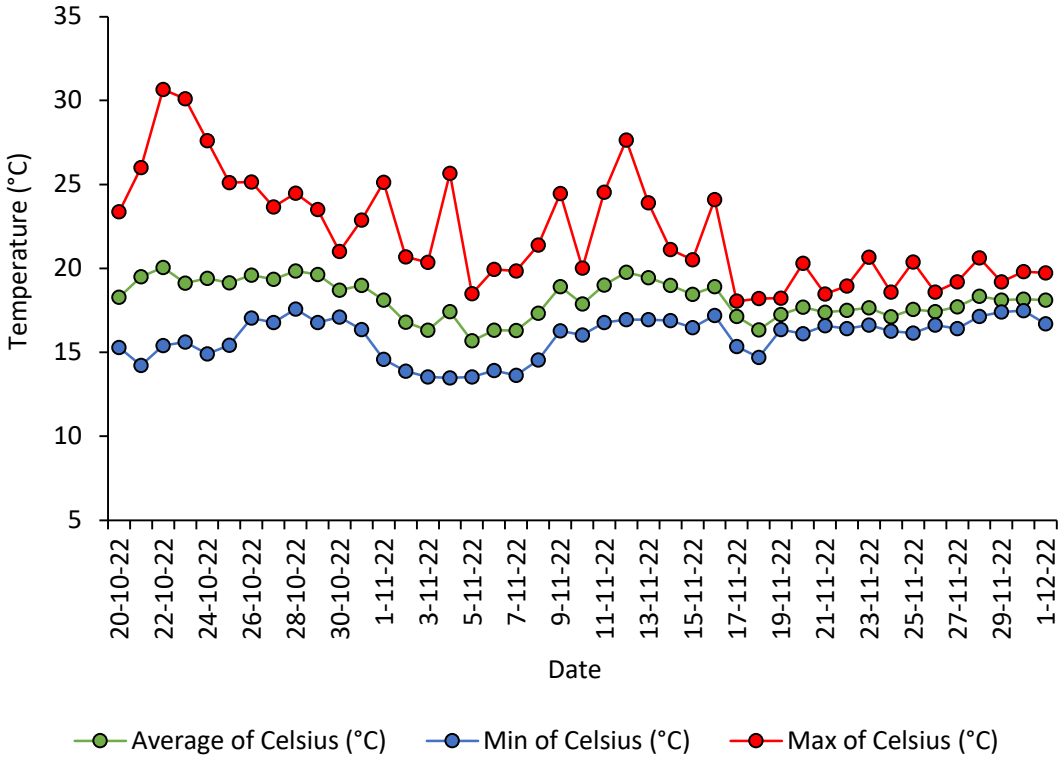
b. Irrigation regime

Plants were irrigated manually, watering twice weekly onto capillary matting beneath the cages. The matting was kept damp throughout the trial.

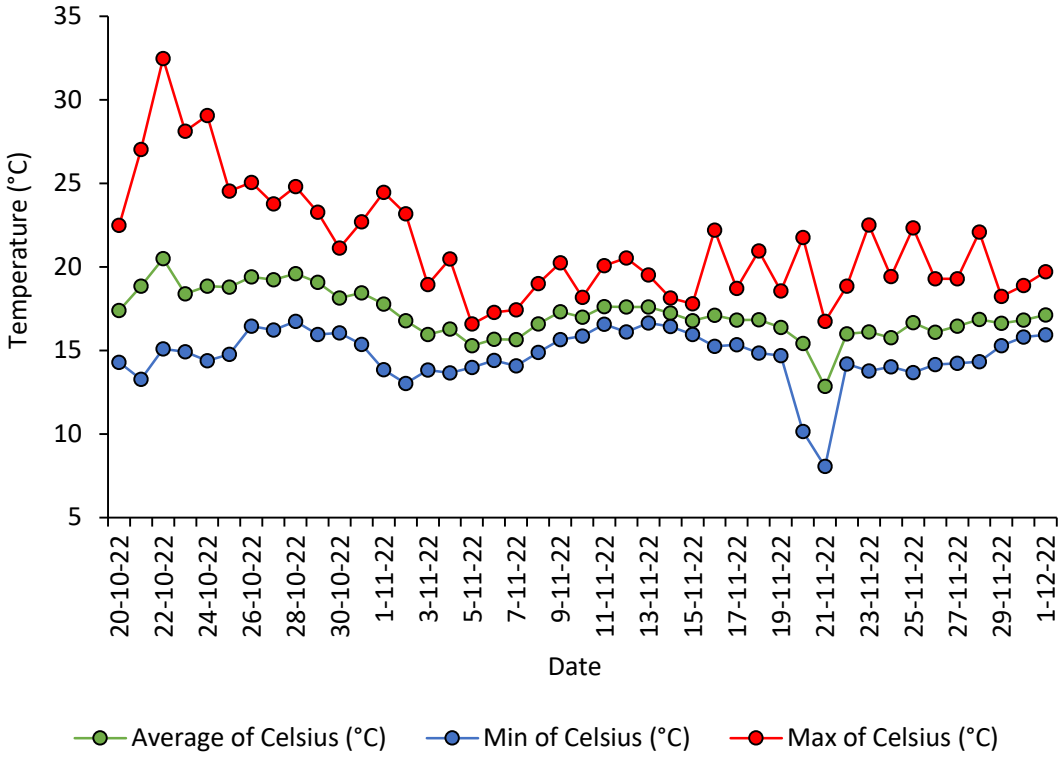
c. Biological control agents applied for other pests

Phytoseiulus persimilis was released on a weekly basis as a prevention against spider mite. No spider mite damage was seen throughout the trial.

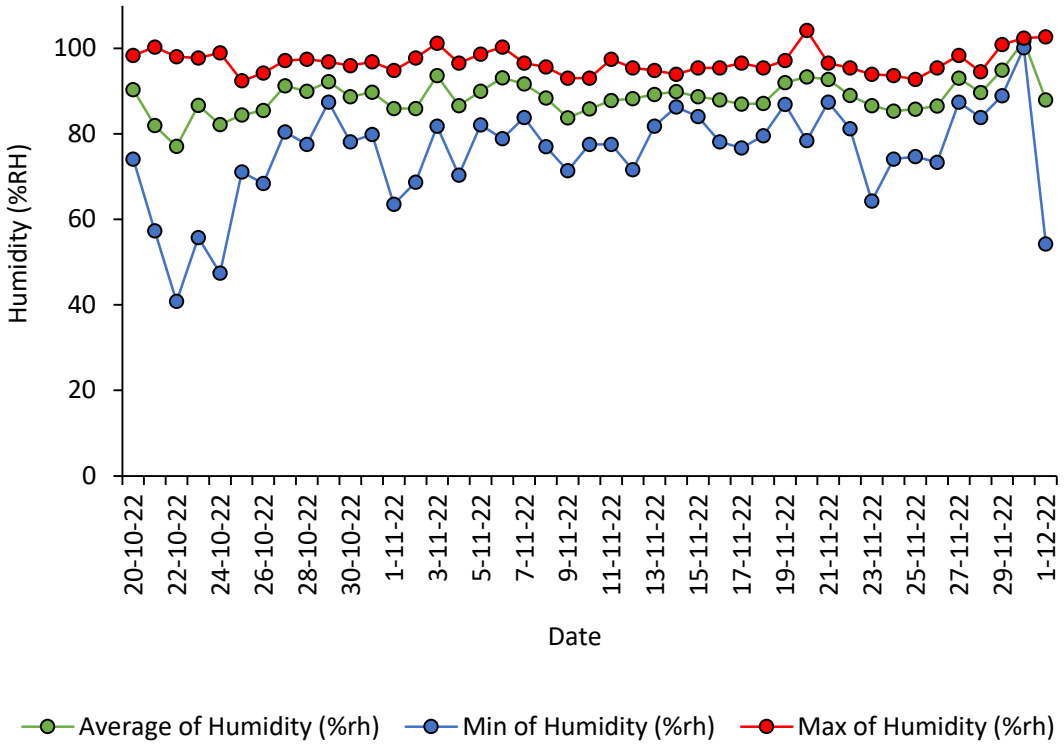
d. Climatological data during study period



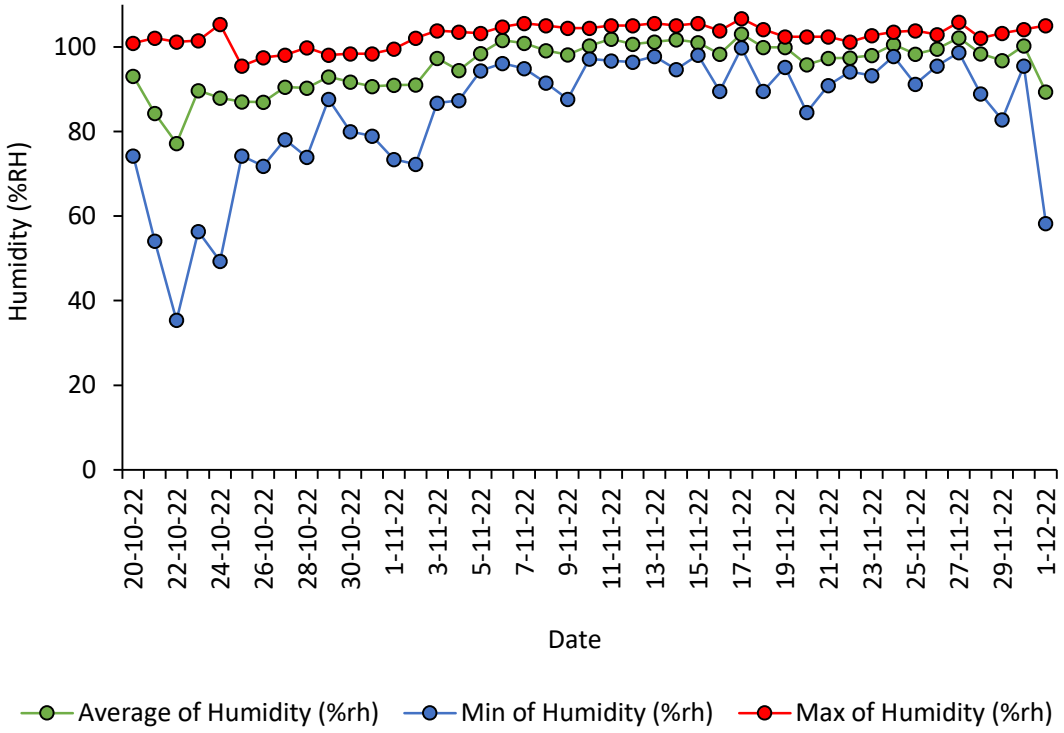
Appendix Figure 1: Glasshouse compartment 4 minimum, maximum, and average temperature (°C) throughout the trial period from infestation of chrysanthemums with onion thrips on 21 October through to the final assessment on 01 December.



Appendix Figure 2: Glasshouse compartment 5 minimum, maximum, and average temperature (°C) throughout the trial period from infestation of chrysanthemums with onion thrips on 21 October through to the final assessment on 01 December.



Appendix Figure 3: Glasshouse compartment 4 minimum, maximum, and average relative humidity (%RH) throughout the trial period from infestation of chrysanthemums with onion thrips on 21 October through to the final assessment on 01 December.



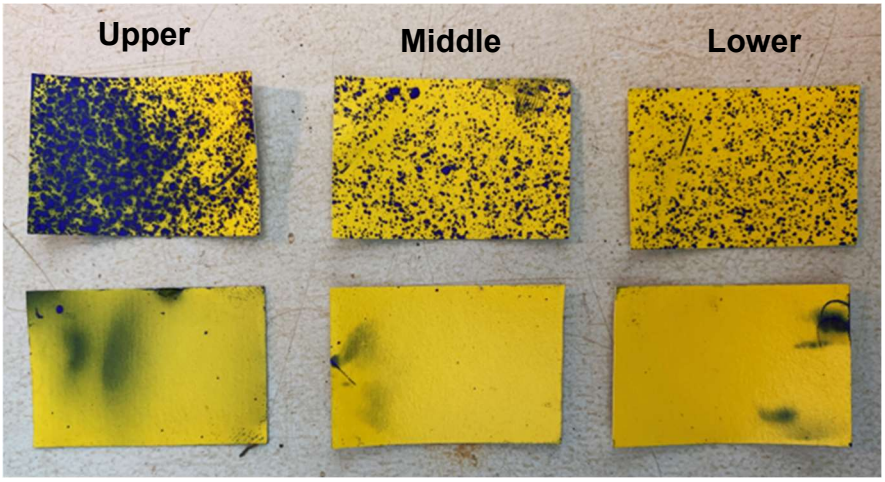
Appendix Figure 4: Glasshouse compartment 5 minimum, maximum, and average relative humidity (%RH) throughout the trial period from infestation of chrysanthemums with onion thrips on 21 October through to the final assessment on 01 December.

e. Raw data

Appendix Table 2: average counts of thrips of onion thrips adults, larvae, and total onion thrips on two assessed leaves on each plant in each plot at each of six assessment dates. Owing to universally low counts and a high incidence of no identified thrips on leaves during several assessment dates, these data were not statistically analysed.

Assessment date	Thrips life stage	Treatment							
		Untreated	Azatin	AHDB 9730	AHDB 9728	Eradicoat® Max	AHDB 9768	AHDB 9729	AHDB 9821
18.10.2022	Adults	0	0	0	0	0	0	0	0
	Larvae	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0
02.11.2022	Adults	0.05	0.02	0.04	0.06	0.02	0.08	0.06	0.06
	Larvae	0	0	0	0	0.02	0.02	0.06	0.04
	Total	0.05	0.02	0.04	0.06	0.04	0.10	0.13	0.10
09.11.2022	Adults	0.05	0.02	0.02	0.04	0.06	0.06	0.06	0.06
	Larvae	0.10	0.13	0.10	0.02	0.02	0.02	0.10	0.10
	Total	0.15	0.15	0.13	0.06	0.08	0.08	0.17	0.17
16.11.2022	Adults	0.05	0.08	0.02	0.15	0.08	0.04	0.04	0.06
	Larvae	0.18	0.17	0.19	0.13	0.06	0.31	0.10	0.15
	Total	0.23	0.25	0.21	0.27	0.15	0.35	0.15	0.21
23.11.2022	Adults	0.10	0	0.02	0.10	0.08	0.04	0.02	0.04
	Larvae	0.03	0.02	0.08	0.04	0.02	0.04	0.04	0.02
	Total	0.13	0.02	0.10	0.15	0.10	0.08	0.06	0.06
30.11.2022	Adults	0.03	0	0.04	0	0.02	0.04	0.02	0.02
	Larvae	0	0.04	0.02	0	0	0	0.04	0
	Total	0.03	0.04	0.06	0	0.02	0.04	0.06	0.02

f. Spray deposition



Appendix Figure 5: Water spray deposition on water-sensitive paper attached to upper, middle, and lower leaves of a potted chrysanthemum plant. Top row: upper leaf surfaces, bottom row: lower leaf surfaces.

g. Phytotoxicity

Appendix Figure 6: Plant growth regulator (B-NINE SG, daminozide, MAPP 14434) induced phytotoxicity: damage photographed on 02 November prior to the first applications of any evaluated plant protection products. Damage was observed in 3 plots (101, 105, 201) in glasshouse compartment 5, with plots in the south-facing corner of this glasshouse compartment receiving the highest degree of sunlight in the trial despite the application of white glasshouse shading paint to the south facing glasshouse panels. B-NINE was applied on 20 October, coinciding with the maximum temperatures reached in the trial on 22 October (30.6°C in Compartment 4, 32.5°C in Compartment 5). Bright sunlight in this south-facing corner of Compartment 5 in combination with the application of B-NINE was most likely responsible for observed phytotoxicity in these three plots – with manufacturer recommendations to avoid spraying in bright sunlight to avoid potential phytotoxic effects.

h. Plant damage

Appendix figure 7: Onion thrips induced flower and leaf damage on chrysanthemum (cv. ‘Rainbow Circus’) on 24 Nov.

i. Trial design

Glasshouse compartment 5

Block 3	**5** 305	**7** 306	**6** 307	**4** 308
	2 301	**8** 302	**1** 303	**3** 304
Block 2	**7** 205	**5** 206	**2** 207	**1** 208
	6 201	**4** 202	**3** 203	**8** 204
Block 1	**8** 105	**3** 106	**6** 107	**5** 108
	2 101	**1** 102	**7** 103	**4** 104

Glasshouse compartment 4

Block 6	**6** 605	**4** 606	**3** 607	**7** 608
	5 601	**1** 602	**2** 603	**8** 604
Block 5	**1** 505	**8** 506	**4** 507	**6** 508
	7 501	**2** 502	**3** 503	**5** 504
Block 4	**1** 405	**5** 406	**8** 407	**6** 408
	4 401	**3** 402	**2** 403	**7** 404

Code	Treatment
1	Untreated (negative control)
2	Azatin (positive control)
3	AHDB 9730
4	AHDB 9728
5	Eradicoat Max
6	AHDB 9768
7	AHDB 9729
8	AHDB 9821

j. **ORETO certificate**

Certificate of

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

This certifies that

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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