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DISCLAIMER

GROWER SUMMARY

Headline

Amblyseius barkeri and *Neoseiulus cucumeris* have potential for curative control of tarsonemid mite infestations in strawberry.

Background and expected deliverables

The strawberry tarsonemid mite, *Phytonemus (Tarsonemus) pallidus* ssp. *fragariae*, sometimes called the strawberry mite, is a serious pest of strawberry. It feeds mainly on the upper surfaces of the young folded leaves of strawberry, making their surfaces rough and crinkled as they expand. Sometimes the leaves turn brown and die and the whole plant usually becomes stunted. Mites also feed in the flowers and fruits, seriously affecting yield and quality.

There has been a significant increase in the frequency and severity of attacks in UK strawberry production in the last few years. The problem was particularly severe in 2010 and 2011, and continues to be a problem in some crops. Because most acaricides are contact acting with no, or at best, limited translaminar activity, it can be difficult to control tarsonemid mite adequately. Although the mites are readily controlled when directly intercepted by an acaricide, penetration into the young folded leaves where the tarsonemid mites live and breed is limited. Spray penetration is the chief factor limiting efficacy. In addition, strawberry leaves are waxy and covered in hairs, and many products are not specifically formulated for the crop and have insufficient wetting properties.

The overall aim of this project is to identify effective predatory mites for prevention and control of strawberry tarsonemid mite in polytunnel and glasshouse crops and to improve application timing and treatment methods.

Summary of the project and main conclusions

In 2012, six predatory phytoseiid mite species were evaluated for their effectiveness at controlling strawberry tarsonemid mite at low and high temperatures, for use in polytunnel and glasshouse conditions. Results from the glasshouse trial were hindered by low numbers of tarsonemid mites in the control plots. However, significantly more tarsonemid eggs were found in plots treated with *Amblyseius swirskii* or *A. montdorensis* compared to those that were treated with *Neoseiulus californicus* and the untreated control. The reason for low numbers of tarsonemid mites on the control is not known, but there were more aphids (although not significant) on control plants so there may have been an interaction between the plant and the two pest species. The summer polytunnel experiment gave more promising results with fewer tarsonemid mites in the plots treated with *A. barkeri* or *N. cucumeris* compared to *A.andersoni* or the untreated control.

The polytunnel trial in 2013 consisted of seven treatments in a randomised block design. *A. barkeri* and *N. cucumeris* were assessed as preventive and curative controls for strawberry tarsonemid mite. The curative controls were applied as one or two releases. There were six replicates per treatment and 10 plants per 1 m grow bag. Each grow bag was a plot and was contained inside a double fleeced open top cage with grease around the top to prevent mites escaping. A pre-assessment and two or three assessments post treatment application (predatory mite release) were made and predatory mites recovered were identified to species.

The trial was hampered in the early stages by the late onset of warm temperatures and the presence of various species of predatory mites in the plots before the treatments had been applied. Both species of predatory mite (*A. barkeri,* and *N. cucumeris*) appeared to suppress introductions of tarsonemid mites made post predatory mite release. Numbers of tarsonemid mites in the untreated control plots remained constant even though *A. barkeri, N. cucumeris* and *N. californicus* were recovered from these plots in substantial numbers. One or two releases of either *A. barkeri* or *N. cucumeris* reduced numbers of tarsonemid mites in the plots.

Although predatory mites (*A. barkeri, N. californicus* and *N. cucumeris*) were found in all plots on all dates, even before the treatment application, they are not restricted to the young folded strawberry leaves and, therefore, may disperse not only over the entire plant but beyond. Drawing conclusions from numbers of predators on young folded leaves is not a reliable way of estimating predatory mite numbers. We hypothesise that higher numbers of predatory mites were recovered from the untreated control because this was where higher concentrations of tarsonemid mites were found. Higher numbers of *A. barkeri* were recovered from all treatment plots compared to *N. californicus* and *N. cucumeris*. However, this dissimilarity could be due to behavioural differences between species rather than estimates of true densities. Large numbers of *A. barkeri* could have overwintered on the site from the 2012 experiment.

Financial benefits

Strawberry tarsonemid mite can cause devastating crop losses in highly valuable protected strawberry crops; losses exceeding £10,000 per ha per annum in some instances. New effective predatory mite species and more accurate timing of application of predators with the most effective species for the time of year will reduce populations of tarsonemid mites in strawberry crops, reducing the need for chemical applications.

Action points for growers

- Results from this study and the study in 2012 suggest that *N. californicus* is to be recommended as an effective treatment for tarsonemid mites in glasshouse strawberry and *A. barkeri* and *N. cucumeris* in polytunnel crops.
- However, tarsonemid mite control is difficult once populations have established and, therefore, we would recommend that growers apply predatory mites early in the season before tarsonemid mite populations can build up.
- It is also important that sprays directed against tarsonemid mites ensure good coverage to the crown and young folded leaves of the plants. We would recommend using water sensitive papers to test this and consider the incorporation of a wetter with the pesticide.
- Growers should follow recommendations for predatory mite release times following a pesticide application.

SCIENCE SECTION

Introduction

The pest

Strawberry tarsonemid mite, *Phytonemus (Tarsonemus) pallidus* ssp. *fragariae,* is a serious pest of strawberry. It feeds mainly on the upper surfaces of the young folded leaves of strawberry, along the main vein, making leaf surfaces rough and crinkled as they expand (Cross, 2003). Sometimes the leaves turn brown and die and the whole plant usually becomes stunted.

Mites also feed in the flowers and fruits, seriously affecting yield and quality. Damage is most severe in everbearing varieties and on plants grown under protection. June bearers can also be severely attacked.

Populations build up rapidly in warm conditions, the generation time being nine days at 25˚C (Smith and Goldsmith, 1936; Wisemann, 1941; Easterbrook *et al*., 2003). The optimum temperature for development is between 22 ˚C and 28˚C (Wisemann, 1941).

Female mites overwinter as adults in the crowns of the plants (Dustan and Matthewman, 1931; Harmsen, 1934; Alford, 1972; Jeppson *et al*., 1975). Oviposition begins at 8˚C (Wisemann, 1941) with each female capable of laying 30-40 eggs during her lifetime (Smith and Goldsmith, 1936). In addition, reproduction is facultatively parthenogenetic (Massee, 1928-30).

<u>Increase in attacks</u>

There has been a significant increase in the frequency and severity of damage in UK strawberry production in the last few years, mostly due to pesticide withdrawals. The problem was at its worst in 2010-11.

Management in UK fruiting plantations

Currently, UK growers use a combination of approaches to control the pest (Table 1).

Difficulty of chemical control

Currently, UK approved chemical options for tarsonemid control on outdoor and protected strawberry are abamectin (Dynamec), fenpyroximate (Sequel) and tebufenpyrad (Masai). Tebufenpyrad (Masai) and abamectin (Dynamec) are only partially effective against *P. pallidus.* The number of applications of abamectin (Dynamec) and tebufenpyrad (Masai) are limited to three and one, respectively, but sprays used during flowering and fruiting on everbearers are undesirable because of residues and harm to non-target invertebrates.

Most acaricides are contact acting with no, or at best limited, translaminar activity. Lack of penetration into the young folded leaves is the chief factor limiting efficacy. Furthermore, strawberry leaves are waxy and covered in hairs, and many products are not specifically formulated for the crop and have insufficient wetting properties.

Work by EMR in HDC project SF 79 (Fountain et al., 2010) clearly demonstrated substantive improvements in the efficacy of abamectin (Dynamec) when admixed with a silicone wetter. Nevertheless a very high degree of efficacy is only likely to be achieved with a systemic acaricide.

Table 1. Current approaches to tarsonemid control

Control/Prevention	Problem
Source clean certified planting material	Often low levels of infestation present
Inspect plantations frequently in spring and early summer for signs of damage and destroy infested plants	As % of infested plants rises, destruction of plants and loss of yield becomes costly and uneconomic
Apply predatory mites	Only partially effective because mites are not suitable for all conditions, timings, and application rates need to be optimised
Spray abamectin (Dynamec) or tebufenpyrad (Masai) when damaging infestations start to develop. Spirodiclofen (Envidor) has an EAMU for protected and outdoor strawberry for spider mite control (2009/3371, until 31/07/2013)	Partial control, delaying the spread of infestation and damage (see below)

Predatory mites tested

The introduction of predatory mites on strawberry is a recommended practice for control of tarsonemid and other pests in strawberry. Early research in the US identified *Typhlodromus* sp. as a controlling predatory mite of tarsonemids on strawberry (Huffaker and Spitzer, 1951; Huffaker and Kennet, 1953). Today, *Neoseiulus cucumeris* is used most commonly for biocontrol of strawberry tarsonemid mite in the UK, but other species may be more efficacious and cost effective.

Biological control, although effective if applied when populations are low to moderate (Croft *et al*., 1998), is slow acting and does not eliminate the pest on whole plants. This is probably because the position of *P. pallidus* in the fold of young strawberry leaves (Easterbrook *et al*., 2001; 2003; Fitzgerald *et al*., 2007; 2008) means that natural enemies need to spend time searching and populations need to build. Larger predators such as anthocorids and *Orius* sp. are not effective because they cannot access the pest.

Repeated and increasing introductions of predatory mites may need to be made until the predator has established (Petrova *et al*., 2002). The most effective species may be temperature dependant, e.g. *A. andersoni* is active from <8 ˚C and *A. swirskii* from 12 ˚C. This will have implications for applications of use. A more voracious predator may be needed if tarsonemid populations peak in high summer.

Neoseiulus barkeri is sold as a preventative treatment for tarsonemid mites. Some other commercially available species are reported to give some reductions in tarsonemid populations although they are not specifically recommended for control of this pest.

In laboratory tests on US species, predation on *P. pallidus* was highest by *Typhlodromus pyri* > *Neoseiulus fallacies* > *Neoseiulus californicus* > *Amblyseius andersoni* > *Galendromus occidentalis* (Croft *et al*., 1998). Other workers found *N. californicus* and *N. cucumeris* to be more effective than *T. pyri* as predators of *P. pallidus* (Fitzgerald *et al*., 2007).

In UK crops *Phytoseiulus persimilis* used to control *Tetranychus urticae* was also found to keep *P. pallidus* in check (Simmonds, 1970). However, this species does not persist on strawberry plants.

Earlier experiments at EMR (Fitzgerald, 2004) showed that *N. californicus* consumed similar numbers of tarsonemids to *N. cucumeris* when they were presented on a leaf arena, but this species was not tested on plants. However, it was found on the old rather than folded leaves. Currently, *N. californicus* may only be used in UK protected crops that are sealed throughout their life. However this species occurs in outdoor crops and efforts are being made to register the mite for use outdoors.

Increasingly *Amblyseius swirskii* and *Amblyseius montdorensis* are being used to control a suite of pests in protected crops. *A. swirskii* has been shown to give good control of broad mite on Azalea (Gobin *et al*., 2011) and *Tarsonemus violae* on gerbera (Pijnakker and Leman, 2011).

The way forward

The potential to exploit new species of predatory mite for the control of tarsonemid mite in strawberry needs to be explored. In addition, the timing and methods of application are very important for the predator to be able to work effectively.

Objectives

The overall aim of the project is to identify effective predatory mites for prevention and control of strawberry tarsonemid mite in polytunnel and glasshouse crops and to improve application timing and treatment methods.

In 2013 the most efficacious species of predatory mite for tarsonemid control in polytunnels, as determined in 2012, were tested at different timings and rates.

1. To determine the most effective timings and application rates of the most efficacious predatory mites to control tarsonemid mites (Table 2).

2. To review the data available on predatory mite compatible chemical treatments in strawberry (postponed from 2012). A desk-based study to review current literature on the toxicity of commonly used commercial pesticides on predatory mites will be compiled. Chemical industry contacts and providers of mite release products will be contacted about specific products to ascertain compatibility of acaricides/insecticides with the use of predatory mites to control tarsonemid mites (this is reported in a separate document March 2014).

Table 2. Two species of predatory mite tested for efficacy for control of tarsonemid mite in strawberry in 2013

Species	Commercially available	Native to UK	Use	Notes
Amblyseius barkeri	Yes	Yes	Polytunnel	Small species may be able to enter folded leaf more effectively
Neoseiulus cucumeris	Yes	Yes	Polytunnel	Commercial standard

Materials and methods

Site

Two dedicated 22 x 6 m Spanish polytunnels in WF221 plot at Rocks Farm (Appendix 1), East Malling Research (by kind permission of Graham Caspell, Farm Manager).

Tarsonemid culture

Infested control plants from the previous year's experiment were kept in two glasshouses at EMR in order to culture the tarsonemid mites. The mite populations were very slow to increase.

Plot infestation

To inoculate the trial plots with tarsonemid mites, young infested leaves from the glasshouse and growers commercial plots were examined by microscope and predatory mites removed (Appendix 1). Leaves were then inoculated into the crowns of plants by placing between the folded young growing leaves on 14, 20, 24 Jun, 4, 15, 18, 24 Jul and 6 and 15 Aug (Table 3). Young leaves from the trial plants in the polytunnel were checked for tarsonemid mites on 3, 23 Jul, 14, 19 Jul and, finally, 22 Aug (Table 3). The numbers of mites present were high but patchy across the plots.

Experimental design and layout

The randomised block experimental design consisted of 42 plots with six replicates of seven treatments (Fig. 1). There were two mite species *Amblyseius barkeri,* and *Neoseiulus cucumeris* (Table 3). Plots consisted of cages made of Horticultural fleece, the cages were double skinned and the open top surface had a coating of 'Fruit tree grease' (Vitax Ltd.) to prevent mites from escaping. Each cage was 50 cm x 50 cm x 100 cm and held 10 strawberry plants (cv. Finesse) planted into a 1 m grow bag (planted in April) which was drip fertigated. Cages were a minimum of 1 m apart.

Table 3. Application programme of predatory mites to strawberry plants to protect against or control tarsonemid mites

Treatment	Species	Timing of predatory mite treatments	No. of predatory mite applications
1	*barkeri*	Pre infestation	1
2	*barkeri*	Post infestation	1
3	*barkeri*	Post infestation	2
4	*cucumeris*	Pre infestation	1
5	*cucumeris*	Post infestation	1
6	*cucumeris*	Post infestation	2
7	Untreated control	-	-

Treatments

Treatments were timed as either preventative (plants inoculated with tarsonemid mites after addition of predatory mites) or as curative (plants inoculated with predatory mites which were already infested with tarsonemid mites) (Table 3). Rates were one or two introductions of phytoseiids for the curative treatment. Two species of phytoseiid were compared.

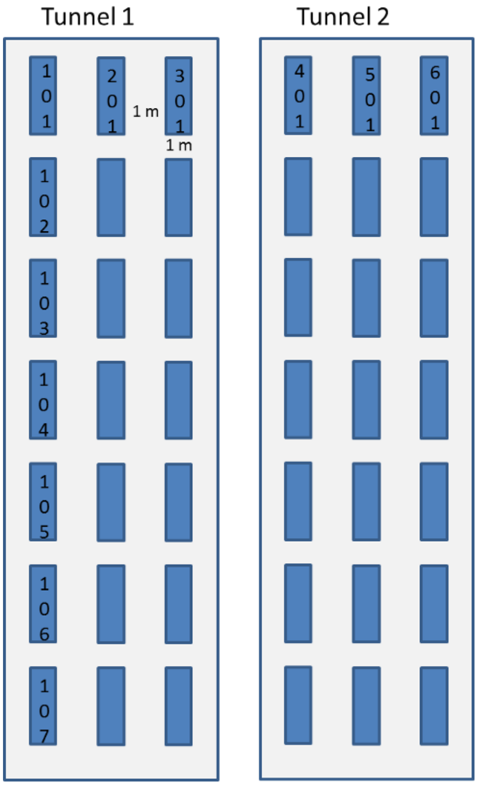

Figure 1. Schematic of experimental plots

Treatment application

All plots, except the untreated controls, were inoculated with releases of predatory mites (Table 2) on 23 Aug. Tarsonemid mites were added to treatments 1 and 4 on 27 Aug, 4 days after inoculation with predatory mites. Treatments 2, 3, 5 and 6 received 20 mites per plant and treatments 1 and 4 received one mite per plant (applied as 10 mites in one tube placed into the crown of the central plant). On 28 Aug treatments 3 and 6 received a second treatment of 20 predatory mites per plant.

Syngenta Bioline recommended 20 mites per m^2 for preventative treatments (peat bags are approximately 1 m x 0.4 m in area = 0.4 m^2 = 10 mites per bag for treatments 1 and 4). For the curative treatments (2, 3, 5 and 6) a rate of 400 mites per m^2 was required (= 200 mites per bag). Mites were transferred from cultures, kindly supplied by Syngenta Bioline, using a one ml filtered pipette tip cut down to make a collection chamber. The mites were individually sucked in to these chambers using a high volume air pump. Ten or 20 mites were collected into each chamber and the chambers capped with para-film. Plants from the same treatment were inoculated simultaneously. Each mite species was set up as an isolated collection station to prevent cross contamination between species. Pipette tips were checked under a microscope to ensure the mites had not been damaged and were moving freely inside prior to introduction to the plants.

Assessments

A pre-treatment assessment was made of the degree of tarsonemid mite infestation on 22 August (Table 3). Five young leaves from each of the plots were collected and examined using a microscope and the numbers of tarsonemid and predatory mites and eggs were recorded. The predatory mite treatments were introduced a day later. Populations of tarsonemid mite and the number of predators in treatments 2, 3, 5, 6 and 7 were assessed on 28 August and all treatments on 3 and 10 September. Five young folded leaves from the crown of the plants (each from a different plant) were collected from each plot and placed in separate polythene bags. The upper and lower surface of each leaf was examined under a microscope in the laboratory. The numbers of tarsonemid and predatory mite motiles and eggs were recorded. Any predatory mites found were mounted onto microscope slides with Hoyer's medium for identification to species under a compound microscope.

Table 3. Dates of activities conduced in the trial

	Treatment	Date
Tarsonemid inoculations	2, 3, 5, 6, 7	14, 20, 24 Jun, 4, 15, 18, 24 Jul, 6, 15 Aug
Pre-assessment	All	22 Aug
Predator introduction	1, 2, 3, 4, 5, 6	23 Aug
Tarsonemid inoculations	1, 4	27 Aug
1st Assessment	2, 3, 5, 6, 7	27 Aug
2nd Assessment	All	3 Sep
3rd Assessment	All	10 Sep

Plot maintenance

All plants were supplied with drip irrigation. The plantation was inspected weekly to check for pests, disease and any other problems. Plants were de-blossomed and de-fruited before the trials were started and on each inspection to encourage new leaf growth favoured by tarsonemid mites. The plots were sprayed with Apollo (clofentezine) on 12 July to control spider mites and Decis (pyrethrin) on 27 and 29 July to reduce numbers of naturally occurring predatory mites which were consuming the inoculations of tarsonemid mites.

Meteorological records

Hourly temperature and humidity records were taken using two Lascar USB-502 loggers in the polytunnel (see appendix 2). For comparison external weather data was collected from the EMR weather station (appendix 3).

Statistical analysis

Repeated measures ANOVA, covariance adjusted for pre-treatment was done where applicable. Analyses were conducted on square root (mean) transformed data.

Results

Because of the difficulty in inoculating the strawberry plants to get sustainable populations of tarsonemid mites, this meant that the control and curative treatment plots were inoculated on eight (Table 3) occasions. The preventative plots were only inoculated once – after predatory mite release. For this reason the preventative treatments cannot be compared to the untreated control.

The numbers of tarsonemid eggs and motiles on the leaves remained low 3 weeks after inoculation with the pest in the preventative treatments (Table 4); 0.2-0.43 and 0-0.53 eggs in the *N. cucumeris* and *A. barkeri* treatments respectively; and 0.43-0.13 and 0.13-0.37 tarsonemid motiles in the *N. cucumeris* and *A. barkeri* treatments, respectively. There was also no significant difference in the numbers of predatory mites or eggs recovered (Table 5).

Table 4. Mean (adjusted for covariate) numbers of tarsonemid mite eggs and motiles per 5 leaves in the preventative treatments

	Tarsonemid eggs				**Tarsonemid motiles**			
	Actual means		**SQRT means**		**Actual means**		**SQRT means**	
Treatment	**27-Aug**	**03-Sep**	**27-Aug**	**03-Sep**	**27-Aug**	**03-Sep**	**27-Aug**	**03-Sep**
N. cucumeris	0.20	0.43	0.082	0.177	0.43	0.13	0.177	0.133
A. barkeri	0.00	0.53	0.000	0.266	0.13	0.37	0.094	0.233
			Treat					
			F pr.	0.98				0.944
			s.e.d.	0.139				0.115
			d.f.	5				5
			l.s.d.	0.358				0.295
			Time					
			F pr.	0.059				0.563
			s.e.d.	0.094				0.082
			d.f.	50				50
			l.s.d.	0.188				0.164
			Treat. Time					
			F pr.	0.366				0.268
			s.e.d.	0.168				0.141
			d.f.	10.33				11.08
			l.s.d.	0.372				0.309

Table 5. Mean (adjusted for covariate) numbers of predatory mite eggs and motiles per 5 leaves in the preventative treatments

	Predatory mite eggs				Predatory mites			
	Actual means		**SQRT means**		**Actual means**		**SQRT means**	
Treatment	**27-Aug**	**03-Sep**	**27-Aug**	**03-Sep**	**27-Aug**	**03-Sep**	**27-Aug**	**03-Sep**
N. cucumeris	0.007	0.007	0.007	0.007	0.219	0.453	0.193	0.342
A. barkeri	0.027	0.027	0.027	0.027	0.281	0.114	0.248	0.121
			Treat					
			F pr.	0.374				0.250
			s.e.d.	0.020				0.061
			d.f.	4				4
			l.s.d.	0.056				0.170
			Time					
			F pr.	1.00				0.898
			s.e.d.	0.024				0.082
			d.f.	50				50
			l.s.d.	0.047				0.165
			Treat. Time					
			F pr.	1.00				0.098
			s.e.d.	0.031				0.102
			d.f.	23				27
			l.s.d.	0.064				0.210

One or two applications of either predatory mite species as a curative treatment reduced the numbers of tarsonemid eggs compared to the untreated control (Table 6). However, by the third assessment, three weeks after the first application there was no significant difference in egg numbers from the control plots. As shown in later results (Fig. 3.3 and 3.1) this may have been because predatory mites not introduced to the plots were beginning to locate and predate on the tarsonemid mites in the untreated control plots. In addition the tarsonemid mites in the treated plots had begun to increase (Table 6).

There were significantly fewer tarsonemid adults found in the third assessment three weeks after the first predatory mite introduction compared to the untreated control (Table 7). One or two releases of *N. cucumeris* or *A. barkeri* were successful at reducing numbers of motile tarsonemid mites.

This suggests that the predators had fed on tarsonemid mites eggs or fecund females by the second week after applications reducing the numbers of motile tarsonemid mites found three weeks after the initial predatory mite release.

Table 6. Mean numbers (adjusted for covariate) of tarsonemid mite eggs per 5 leaves in the curative treatments

Treat/applic. frequency	**Actual means**			**SQRT means Time**		
	27-Aug	**03-Sep**	**10-Sep**	**27-Aug**	**03-Sep**	**10-Sep**
A. barkeri curative x1	5.79	1.42	4.52	1.506a	0.653b	0.891a
A. barkeri curative x2	9.13	1.73	2.83	1.512a	0.655b	0.871a
N. cucumeris curative x 1	7.05	0.62	1.52	1.277a	0.530b	0.899a
N. cucumeris curative x 2	2.81	1.18	2.81	0.957a	0.315b	0.724a
Untreated	4.52	4.95	3.38	1.172a	1.460a	1.120a
			Covariate			
			F pr.	0.052		
			Treat			
			F pr.	0.234		
			s.e.d.	0.248		
			d.f.	19		
			l.s.d.	0.519		
			Time			
			F pr.	0.009		
			s.e.d.	0.181		
			d.f.	229		
			l.s.d.	0.361		
			Treat.Time			
			F pr.	0.6		
			s.e.d.	0.412		
			d.f.	120		
			l.s.d.	0.828		

Table 7. Mean numbers (adjusted for covariate) of tarsonemid mites per 5 leaves in the curative treatments

Treat/applic. frequency	Actual means			SQRT means Time		
	27-Aug	03-Sep	10-Sep	27-Aug	03-Sep	10-Sep
A. barkeri curative x1	4.55	1.18	2.51	1.388a	0.539b	0.968b
A. barkeri curative x2	7.18	1.88	2.65	1.705a	0.757b	0.814b
N. cucumeris curative x 1	6.93	1.63	2.76	1.725a	0.829b	1.117b
N. cucumeris curative x 2	4.23	1.83	2.17	1.601a	0.549b	0.836b
Untreated	2.68	4.31	5.48	1.172a	1.411a	1.748a

Covariate	
F pr.	0.09
Treat	
F pr.	0.215
s.e.d.	0.2141
d.f.	19
l.s.d.	0.4481
Time	
F pr.	<.001
s.e.d.	0.1599
d.f.	232.72
l.s.d.	0.3189
Treat.Time	
F pr.	0.111
s.e.d.	0.3613
d.f.	129.01
l.s.d.	0.7239

From the very beginning of the experiment predatory mites were found on the strawberry plants, even before the treatments were applied. Pre assessments on random samples of leaves identified three *N. barkeri*, two *N. cucumeris* and one *N. californicus* on 23 Jul and *A. barkeri* was also present on the leaves on 24 Jun and 29 Jul. These predatory mites interfered with the establishment of tarsonemid mites early on in the project and so on 27 and 29 Jul, to reduce numbers of predatory mites, a spray of Decis was applied with an air assisted knapsack sprayer. The numbers of predators per leaf were 0.26 on 3 Jul, 0.19 on 23 Jul, 0.07 on 14 Aug and 0.19 on 19 Aug.

Although there was little difference in the numbers of predatory mite eggs found on the young folded leaves of the strawberry plants (Table 8) significantly more motile predatory mites were found in the untreated control plots – where no mite releases had been made – by the end of the trial (Table 9).

Table 8. Mean numbers (adjusted for covariate) of predatory mites per 5 leaves in the curative treatments

Treat/applic. frequency	**Actual means**			**SQRT means Time**		
	27-Aug	03-Sep	10-Sep	27-Aug	03-Sep	10-Sep
A. barkeri curative x1	0.668	0.402	0.602	0.543b	0.361a	0.518c
A. barkeri curative x2	0.434	0.400	0.467	0.372a	0.355a	0.363b
N. cucumeris curative x 1	0.363	0.363	0.296	0.353a	0.331a	0.267b
N. cucumeris curative x 2	0.534	0.334	0.334	0.434a	0.289a	0.273b
Untreated	0.267	0.334	1.234	0.265a	0.251a	0.723a

Covariate	
F pr.	0.794
Treat	
F pr.	0.332
s.e.d.	0.083
d.f.	19
l.s.d.	0.174
Time	
F pr.	0.234
s.e.d.	0.067
d.f.	248
l.s.d.	0.132
Treat.Time	
F pr.	0.1
s.e.d.	0.147
d.f.	145
l.s.d.	0.292

Table 9. Mean numbers (adjusted for covariate) of predatory mite eggs per 5 leaves in the curative treatments

Treat/applic. frequency	Actual means			SQRT means Time		
	27-Aug	03-Sep	10-Sep	27-Aug	03-Sep	10-Sep
A. barkeri curative x 1	0.695	0.095	0.029	0.266b	0.079a	0.032a
A. barkeri curative x 2	0.329	0.262	0.162	0.223b	0.120a	0.099a
N. cucumeris curative x 1	0.162	0.295	0.062	0.123a	0.126a	0.046a
N. cucumeris curative x 2	0.119	0.152	0.052	0.063a	0.096a	0.039a
Untreated	0.162	0.029	0.095	0.073a	0.032a	0.056a

Covariate	
F pr.	0.731
Treat	
F pr.	0.43
s.e.d.	0.056
d.f.	19
l.s.d.	0.117
Time	
F pr.	0.164
s.e.d.	0.050
d.f.	217
l.s.d.	0.101
Treat.Time	
F pr.	0.861
s.e.d.	0.107
d.f.	163
l.s.d.	0.216

Predatory mites from the three assessment dates were identified to species where possible. *A. barkeri* was the most prevalent species in all of the plots throughout the trial, even in the plots where it was not introduced (Fig. 2 – 4). *N. californicus* and *N. cucumeris* were also recovered from the leaves on most of the plots. Even *N. californicus,* which was not introduced as part of this study and is not approved for outdoor release, was detected on the young strawberry leaves (27 Aug, Fig. 5). Figure 5 summarises the mites identified throughout the study and it can be seen that all 3 species are common through the trial.

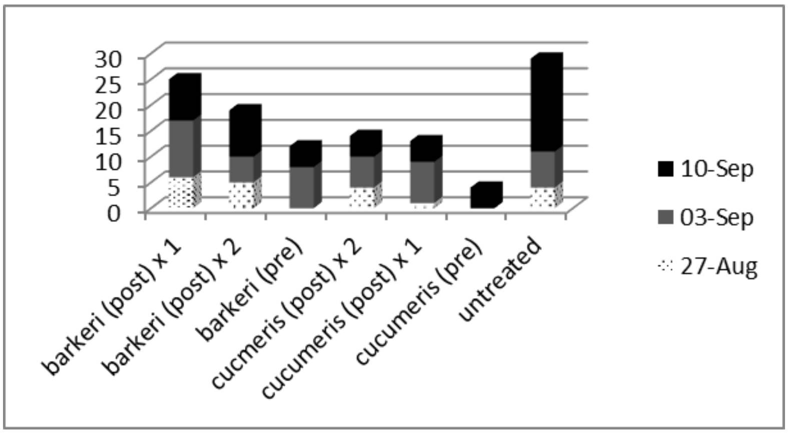

Figure 2. Total numbers of *A. barkeri* identified on all plots on the three assessment dates in the different treatments

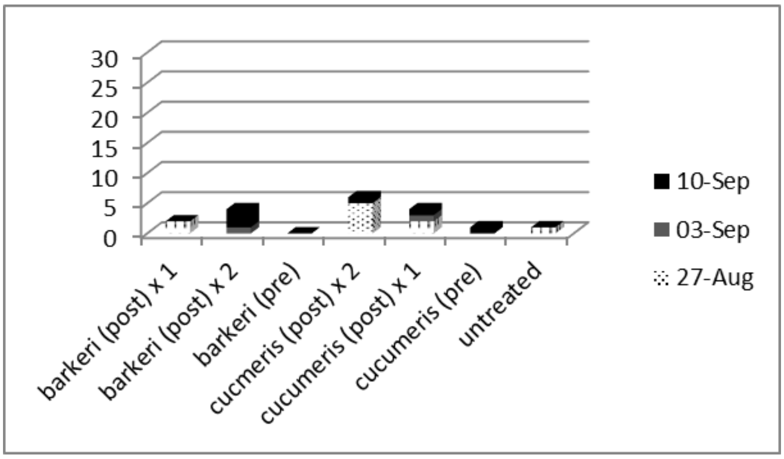

Figure 3. Total numbers of *N. cucumeris* identified on all plots on the three assessment dates in the different treatments

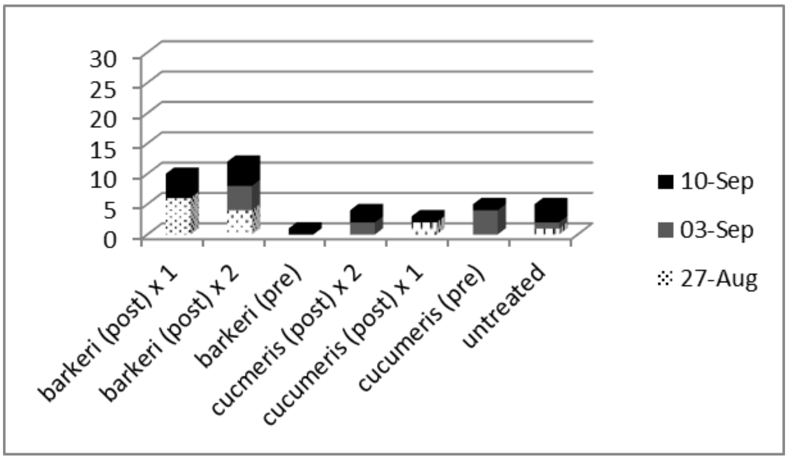

Figure 4. Total numbers of *N. californicus* identified on all plots on the three assessment dates in the different treatments

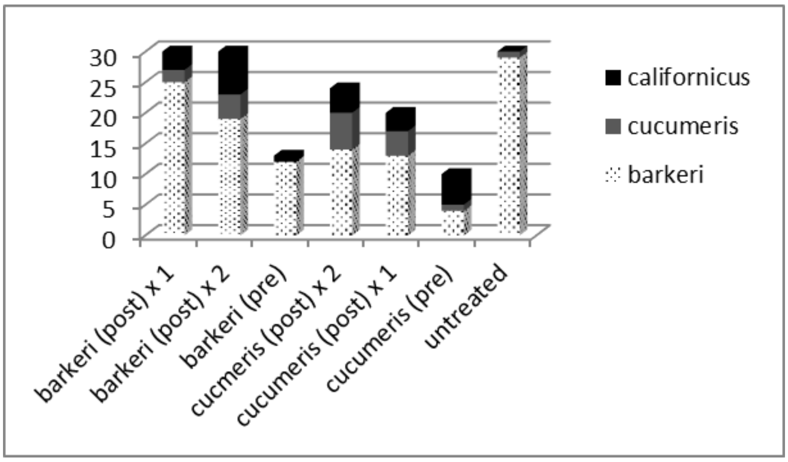

Figure 5. Total number of predatory mite species identified found in all of the plots over the course of the trial (*N. californicus, N. cucumeris* and *A. barkeri*)

A regression analysis using a GLM (taking into account the Poisson distribution of the data) of adult predators vs. motile tarsonemid mites for all four dates on each treatment showed that on all dates there was a significant correlation between tarsonemid numbers and predator numbers ($p<0.001$, $p=0.008$, $p=0.002$, $p<0.001$ for assessments on 22 Aug, 27 Aug, 3 Sep and 10 Sep; corresponding slopes were 0.0448 (+/-0.0143), 0.0216(+/-0.0084), 0.0421(+/-0.0153), 0.0713(+/-0.0159) (Fig. 6).

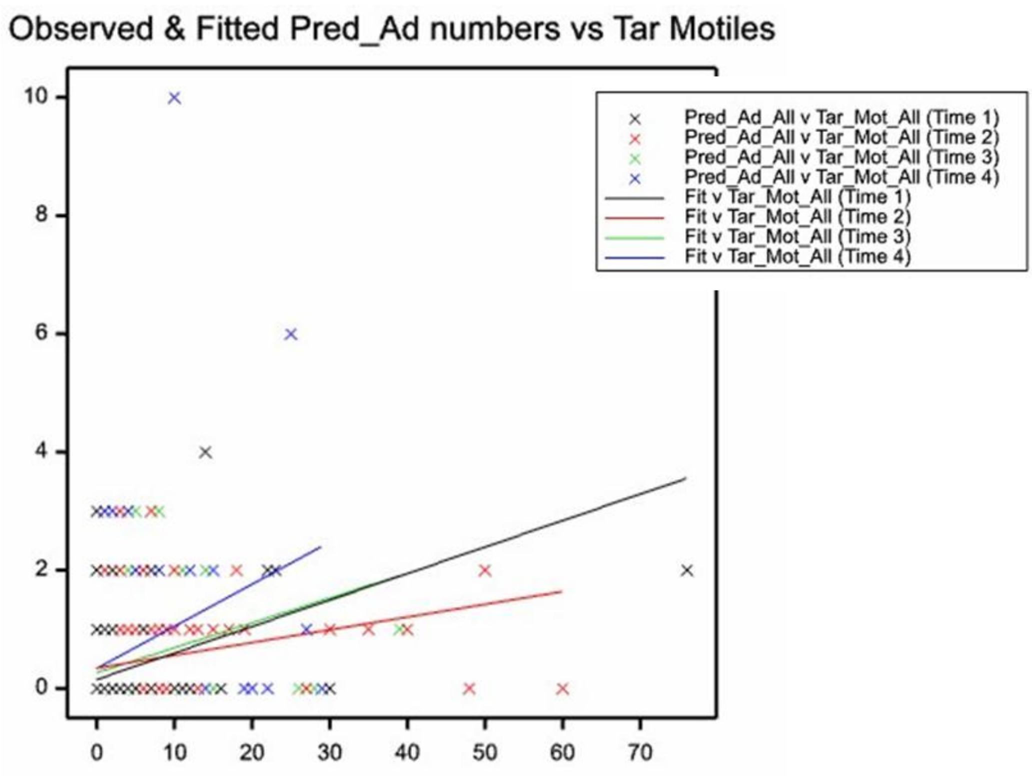

Figure 6. Regression of the number of predatory mite vs. tarsonemid mites on all four sampling dates

Conclusions

- Both species of predatory mite (*A. barkeri, N. cucumeris*) appeared to suppress introductions of tarsonemid mites made post predatory mite release.
- Numbers of tarsonemid mites in the untreated control plots remained constant even though predatory mites were recovered from these plots in substantial numbers.
- Using *A. barkeri* or *N. cucumeris* to reduce numbers of tarsonemid mites was successful for the length of the trial. One or two releases of *N. cucumeris* or *A. barkeri* were effective.
- Predatory mites were found in all plots on all dates, even before the treatment application, and are not as restricted to the young folded leaves inhabited by tarsonemid mites and, therefore, may disperse not only over the entire plant but, also, beyond. Hence, drawing conclusions from numbers of predators on young folded leaves is not a reliable way of estimating predatory mite numbers in strawberry crops.
- We hypothesise that higher numbers of predators were recovered from the untreated control because this is where higher concentrations of tarsonemid mites were found.
- Higher numbers of *A. barkeri* were recovered from all treatment plots compared to *N. californicus* and *N. cucumeris*. However, this dissimilarity could be due to behavioural differences between species rather than estimates of true densities.
- Large numbers of *A. barkeri* could have overwintered on the site from 2012 experiment.

Future work

In the final year of the project we will test the most successful predatory mite species and application strategies in a field trial in strawberry under polythene. *A. barkeri* can only be released in loose formulation. *N. cucumeris* is available in loose, slow release sachets and slow release rolls. The researchers will consult with the industry lead on the best way forward for the project in 2014.

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We are grateful to Graham Caspell and his team for the erection and maintenance of the polytunnel and husbandry of the plants. We would also like to thank Bethan Shaw, Matteo Maltese and Zsuzsanna Hajdu of EMR, who assisted with the spraying, sampling, mite counts and phytoseiid mite identification. Many thanks also to Steve Greenaway who supplied many of the samples of tarsonemid mites for inoculation.

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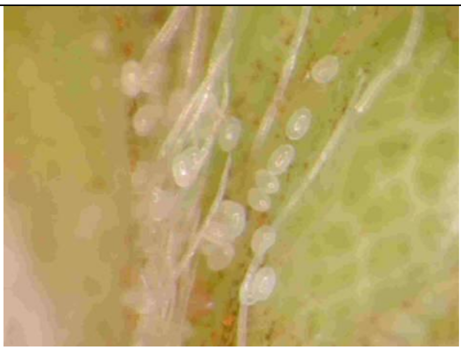
Appendix 1.

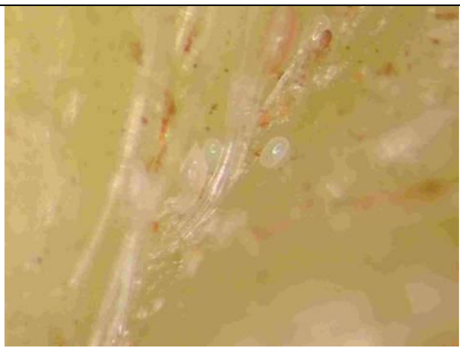
Photographs from HDC strawberry trial

1



Tarsonemid mite eggs

2



Tarsonemid mite eggs and nymph

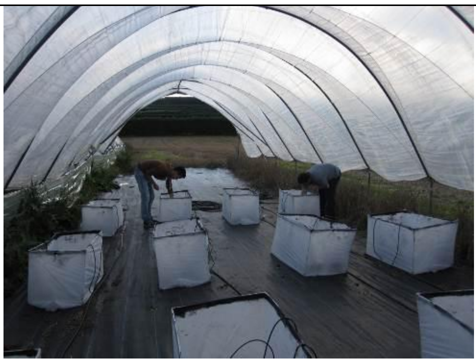
3

Tarsonemid mite adult

4

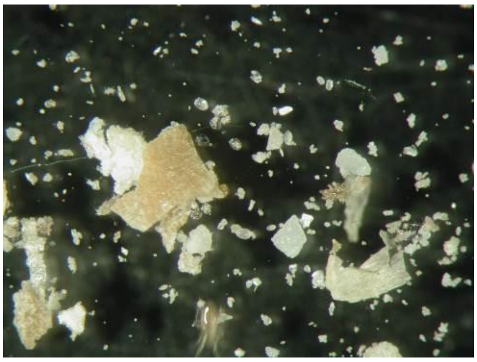
Tarsonemid damage to strawberry leaf

5



Polytunnel and cages used in trial, Autumn 2012

6

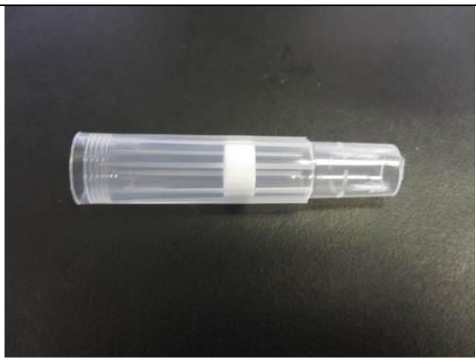


Predatory mites from cultures

7

Pump and pooter apparatus

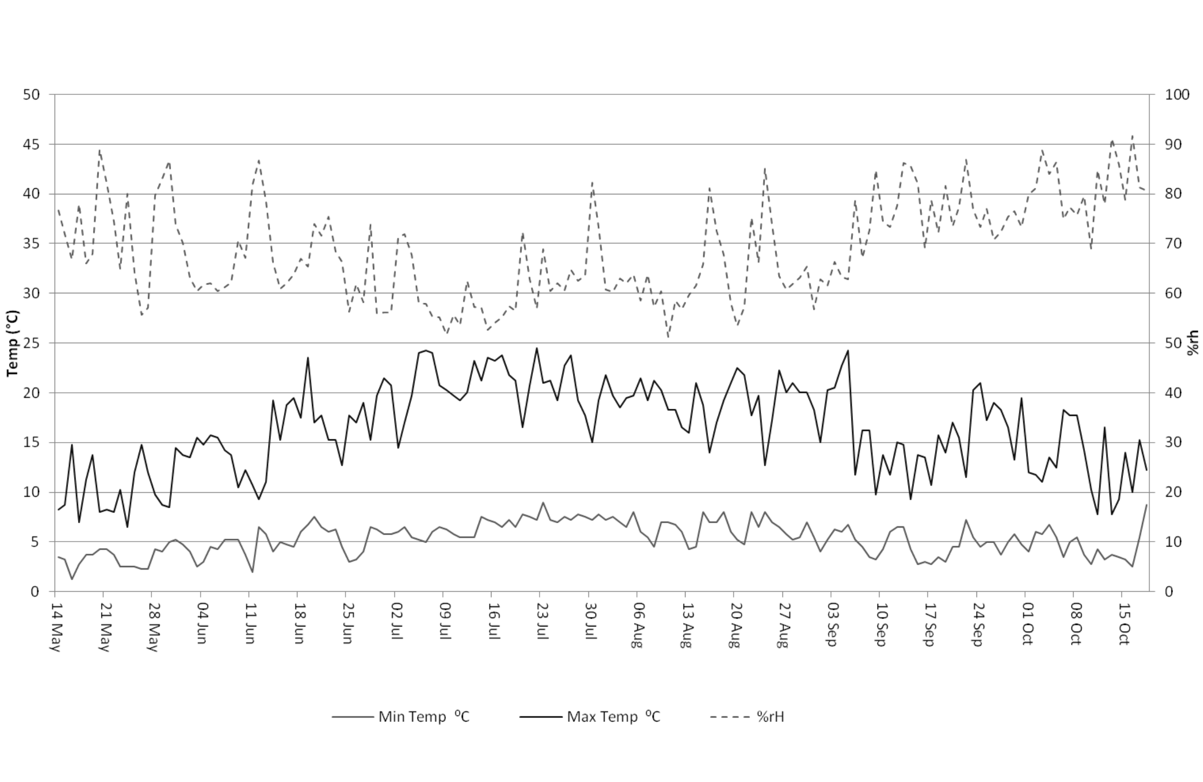
8



Modified pipette tip for pooting predatory mites

Appendix 2.

Mean half hour weather data from 2 lascar 502 temperature and humidity loggers for the duration of the experiment I the poly tunnel in 2013



Appendix 3.

Mean daily weather data from the EMR weather station for the duration of the experiment