Project Title:	Evaluation of foliar sprays of acaricides for control of tarsonemid mite in strawberry 2012
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tarsonemid mite, acaricides, *Phytonemus (Tarsonemus) pallidus* ssp. *fragariae*, strawberry, abamectin (Dynamec), spirodiclofen (Envidor), tebufenpyrad (Masai), fenpyroximate (Sequel), etoxazole (Borneo)

DISCLAIMER

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GROWER SUMMARY

Headline

- Trials demonstrated that good coverage sprays of Dynamec, Masai or a new novel product plus Silwet can reduce infestations of tarsonemid mite 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 which can halt berry production..

There has been a significant and threatening increase in the frequency and severity of attacks in UK strawberry production in the last few years and the problem was particularly bad in 2010 and 2011, though the problem abated in 2012.

Controlling strawberry tarsonemid mite can be particularly difficult as most acaricides are contact acting with no, or at best limited, translaminar activity. The mites are readily controlled when directly intercepted by an acaricide, but penetration into the young folded leaves where the tarsonemid mites live and breed is limited; spray penetration being 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 clearly demonstrated substantive improvements in the efficacy of abamectin (Dynamec) when admixed with a silicone wetter.

There is a clear need to identify new, more effective spray treatments for tarsonemid mite. Ideally, these need to be compatible with biocontrol agents as well as being safe to plants, the environment and humans.

The overall objective of this trial was to identify new effective acaricide treatments for control of strawberry tarsonemid mite in propagation and/or fruiting crops.

Summary of the project and main conclusions

In the first year of the project (2011), tarsonemid mite populations on the strawberry plants failed to build up to more than a few per leaflet, despite repeated attempts at artificial infestation. As a result few results and conclusions could be drawn on the efficacy of the control measures applied.

The experiment was repeated in 2012 with a different strawberry variety. Repeated introductions of tarsonemid mite infested strawberry leaves were made by placing them in between the leaflets of young trifoliate leaves. We evaluated seven day programmes of up to three sprays (not exceeding the maximum number of applications permissible) of Envidor, Masai, Sequel, Borneo, SAF-T-SIDE, Naturalis L, and 5 HDC coded products at their full recommended rates. Envidor, Masai, Sequel, Borneo, SAF-T-SIDE and 4 of the coded products were used in admixture with the silicone wetter Silwet L77. Single and three spray treatments of Dynamec+Silwet L77, and a three spray treatment with Silwet L77 were included as standards. Assessments included counts of tarsonemid motiles and eggs. Plants were assessed for any phototoxicity effects.

Four of the product combinations tested significantly reduced populations of tarsonemid mites (motiles and eggs) compared to the untreated controls. These were a single spray of Dynamec+Silwet L-77, three sprays of Dynamec+Silwet L-77, a single spray of Masai+Silwet L-77 and three sprays of the novel compound HDCB 004+Silwet L-77. The results show that Dynamec, the positive control, is still the most effective of the commercially available products and there was no significant difference between a single or three spray applications. A single application of Sequel+Silwet L-77, while not statistically significant, did reduce the numbers of eggs and the numbers of motile mites. This may be of some use, in conjunction with other modes of action, for resistance management programmes. HDCB 004 offered the most promise for future control of tarsonemid mite and is the highest priority for further investigation.

Financial benefits

Strawberry tarsonemid mite can cause devastating crop losses in highly valuable protected strawberry crops, with losses exceeding £10,000 per ha per annum in some instances. New effective chemical treatments for control typically cost <£100 per ha per application, so the cost benefit ratio of any new acaricide treatment is likely to be very high and will benefit UK strawberry propagators and fruit producers.

Action points for growers

- Sprays of Dynamec+Silwet L77 still offer the best available curative treatment for strawberry plants infested with tarsonemid mites, although three sprays seven days apart offered no benefit compared to one spray in this work.
- The use of Sequel+Silwet L77 is recommended as part of a resistance management spray programme.
- The key to effective control with these products is good spray coverage with high water volumes.
- Growers should always aim to prevent the build-up of tarsonemid mites by using commercially available predatory mites introduced early in the season.
- Monitoring should include looking for both mites and eggs, not just damaged leaves, which may have resulted from old damage.

SCIENCE SECTION

Background

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 (Appendix 1). Sometimes the leaves turn brown and die and the whole plant usually becomes stunted. Mites also feed in the flowers and fruits, seriously affecting berry production, 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. There has been a significant and threatening increase in the frequency and severity of attacks in UK strawberry production in the last few years and the problem was particularly bad in 2010 and 2011, though the problem abated in 2012.

The difficulty of controlling strawberry tarsonemid mite is because most acaricides are contact acting with no, or at best limited, translaminar activity. The mites are readily controlled when directly intercepted by an acaricide, but penetration into the young folded leaves, where the tarsonemid mites live and breed, is limited; 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 (report issued 2 Jan 2008) 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.

Currently UK growers use a combination of approaches to control the pest:

(1) They source clean certified planting material; but experience shows that the material from the main Dutch and Spanish suppliers often has low levels of infestation.

(2) Plantations are inspected frequently in spring and early summer for signs of damage and infestation and infested plants are grubbed and destroyed; however this approach rapidly becomes costly and uneconomic.

(3) *Amblyseius* predatory mites are introduced to prevent or suppress outbreaks; but this approach is only partially effective and cannot contain outbreaks in hot weather conditions.

(4) Sprays of abamectin (Dynamec) or tebufenpyrad (Masai) when damaging infestations start to develop are applied and give partial control so delaying the spread or infestation and damage. The number of applications of abamectin (Dynamec) and tebufenpyrad (Masai) are limited to three and one respectively, and in any event sprays used during flowering and fruiting on everbearers are undesirable.

Fountain *et al*. (2010) reported the results of HDC project SF 79, an experiment at East Malling Research in 2007, which determined the efficacy of acaricides for controlling tarsonemid mite in polytunnel-protected everbearer strawberry plants in grow bags. Treatments evaluated included both approved acaricides (Dynamec and Masai) at recommended and non-recommended rates, along with novel products. Some treatments were applied in admixture with the silicone adjuvant Silwet L-77. The trial confirmed the importance of the use of a silicone wetter with acaricide products. Only a novel product (HDCB 004) in admixture with Silwet and Dynamec 500ml+Silwet reduced all life stages of the tarsonemid mite compared to the untreated control.

Objective

The objective of this study was to identify new effective acaricide treatments for control of strawberry tarsonemid mite in propagation and/or fruiting crops.

Materials and methods

Experimental design

A small plot replicated experiment comparing foliar sprays of the acaricidal products was carried out on everbearer strawberry plants (cv. Finesse) artificially infested with tarsonemid mite in a polytunnel at East Malling Research (EMR) between March and September 2011.

Tarsonemid culture

Infested control plants from the previous year were kept in two glasshouses at EMR in order to culture the tarsonemid mites. Approximately 100 elite Finesse cold-stored strawberry runner plants were planted into individual pots and placed amongst the infested plants (Appendix 1) to increase the number of inoculation plants available for the trial. In addition, through an agronomist adviser, a commercial plantation was identified and leaves and runners collected from the crop before treatment. The mite populations were very slow to increase (Appendix 1).

Plot infestation

To inoculate the trial plot with tarsonemid infected leaves from the glasshouse culture, young trifoliate leaves were collected and on 8 May, 6 June and 2 July infested leaves were placed in-between the leaflets of young trifoliate leaves of each plant. Young leaves from the strawberry plants in the polytunnel were checked for tarsonemids on 10 July.

Experimental design and layout

The experimental strawberry plantation consisted of 64 plots in a 22 x 6 m Spanish polythene tunnel (EMR plot code WF211) remote from other strawberry plantations. A randomised block experiment design with four replicates of 16 treatments was used. Each plot consisted of a standard 1 m peat bag planted with 10 Finesse everbearer strawberries on 3 May 2012. Each bag was provided with trickle irrigation/fertigation. The plots were arranged in four rows of 16 within the polytunnel and plots were separated by 0.5 m (Appendix 1).

Treatments

Treatments were seven day programmes of up to three sprays (not exceeding the maximum number of applications permissible) of Agrimec, Envidor, Masai, Sequel, Borneo, Naturalis L, HDC coded products HDCB 004, HDCB 005, HDCB 006, HDCB 007, HDCI 011 and HDCI 012 at their full recommended rate for curative control of tarsonemid mite on strawberry. Agrimec, Envidor, Masai, Sequel, Borneo, HDCB 004, HDCB 005, HDCB 006, HDCI 011 and HDCI 012 were used in admixture with the silicone wetter Silwet L77. Naturalis L and HDCB 007 were not used in admixture with Silwet L77. Single and three spray treatments of Agrimec + Silwet L77, and a three spray treatment of Silwet L77 were included as standards (Table 1).

Treatment application

Treatments were applied at a volume rate of 1,000 l/ha using knapsack sprayer with a hand lance (not air-assisted). This minimised inter-plot contamination by spray drift. The accuracy of application of each treatment was estimated by measurement of the amount of spray that had actually been applied (calculated from the initial minus the final volume of sprayate left in the tank, minus the amount that should have been left had the spray been applied at exactly the correct volume rate). Applications were generally within 10% of required (Table 2), although some larger deviations occurred. This was found to be due to a loose internal factory fitting in a new sprayer that was used.

Table 1. Treatments

Trt No.	Product(s)	Product rate/ha (spray volume 1000 l/ha)	Day of application		
			0	**7**	**14**
1	Agrimec+Silwet L-77	500 ml	1	0	0
2	Agrimec+Silwet L-77	500 ml	1	1	1
3	Envidor+Silwet L-77	400 ml	1	0	1
4	Masai+Silwet L-77	750 g	1	0	0
5	Sequel+Silwet L-77	2.0 l	1	0	0
6	Borneo+Silwet L-77	350 ml	1	0	0
7	Naturalis L	3.0 l	1	1	1
8	HDCB 004+Silwet L-77	1.0 l	1	1	1
9	HDCB 005+Silwet L-77	20 l	1	1	1
10	HDCB 006+Silwet L-77	10 l	1	1	1
11	HDCB 007	2.5 l	1	1	1
12	HDCI 011+Silwet L-77	1.0 l	1	0	1
13	HDCI 012+Silwet L-77	20.0 l	1	1	1
14	Silwet L-77	50 ml	1	1	1
15,16	Untreated	-	-	-	-

Table 2. Accuracy of spray application estimated from the amount of sprayate remaining in the spray tank after application

Treatment		Accuracy of application (%)			
		13 Jul	**20 Jul**	**27 Jul**	**02 Aug**
1	Dynamec+Silwet L-77	125*	-	-	-
2	Dynamec+Silwet L-77	125*	105	100	-
3	Envidor+Silwet L-77	100	-	100	-
4	Masai+Silwet L-77	100	-	-	-
5	Sequel+Silwet L-77	80*	-	-	-
6	Borneo+Silwet L-77	98	-	-	-
7	Naturalis L	90	100	100	-
8	HDCB 004+Silwet L-77	90	100	92	-
9	HDCB 005+Silwet L-77	85*	80	90	-
10	HDCB 006+Silwet L-77	85*	10	100	-
11	HDCB 007†	†	104	100	100
12	HDCI 011+Silwet L-77	100	-	100	-
13	HDCI 012+Silwet L-77	95	95	100	-
14	Silwet L-77	90	100	100	-

*Notes: * internal pipe on new sprayer was loose, resulting in fluctuating pressure.*
† sample delayed in post by courier

Assessments

A pre-treatment assessment was made (10 July 2012) of the degree of tarsonemid mite infestation in the polytunnel. Three young trifoliate leaves from each of the plots were collected and examined using a microscope and the number of tarsonemid mites and eggs recorded. A note was made of any potential predators.

The effects of the treatments were assessed four days after the first application (13 July 2012), six days after the second application (26 July 2012) and again six days after the third application (02 August 2012). The product HDCL 007 arrived late, and hence, was applied seven days late.

Assessments were done on 17, 26 July and 02 August. Because of the delay in receiving HDCB 007 an assessment was conducted for both the untreated control and this product alone seven days later (9 August 2012). The numbers of tarsonemid eggs and motiles on 10 young folded trifoliate leaves per plot (grow bag) were counted under a binocular microscope. The upper and lower surface of each trifoliate leaf was examined. Predatory mites were also counted on the same leaves.

The trial was assessed for levels of damage caused by mites. Stunting of growth and crinkling of leaves was recorded on all 10 plants on each plot on 8 August 2012 using a four point scale:

- 0 = no damage
- 1 = slight damage
- 2 = moderate damage
- 3 = severe damage

Plot maintenance

Glasshouse plants were watered directly daily. Trickle irrigation/fertigation was supplied to the plants in growbags in the polytunnel. There was a normal overall spray programme of fungicides for mildew control. Parasitoid wasps were introduced for aphid control. The plantation was inspected weekly to check for pests, disease and any other problems. Plants were de-flowered and de-fruited at the same time to encourage new leaf growth, which favours tarsonemid mites.

Meteorological records

Dry and wet bulb temperature, and wind speed and direction were recorded before and after each spray application. Relative humidity (rh%) was estimated from the dry and wet bulb temperature readings (Table 3). In addition, two Lascar USB-502 loggers were used to take hourly temperature and humidity readings inside the polytunnel throughout the trial (Appendix 2).

Table 3. Weather conditions at the time of spray application. N/A = Not applicable

Date	Time	Air temperature			Wind	
		°C dry	°C wet	% rh	speed (Kmh)	direction
13 Jul	10:10	17	15	80	0	N/A
20 Jul	08:06	17	16	90	0	N/A
27 Jul	07:50	16	16	100	0	N/A
02 Aug	17:00	21	16	60	0	N/A

Statistical analysis

Analyses were done by repeated measures ANOVA, covariance adjusted for pre-treatment with data $Log_{10}(n+1)$ or angular transformed as appropriate. The product HDCL 007 was analysed in comparison to the control separately from the rest of the products due to the late arrival of the sample.

Experimental approval and crop destruction

The novel coded products were not approved for use on strawberry and an experimental approval was acquired for all non-approved products by EMR. No fruit was harvested and the experimental plants were destroyed at the end of the experiment.

Phytotoxicity

Determination of any phytotoxic effects of the treatments was not a central aim of this work. However, plots were inspected for any visual signs of phytotoxicity from the treatments on each sampling occasion.

Quality assurance

East Malling Research is an officially recognised efficacy testing organisation (Certificate no. 0232). The work was done according to GEP quality standards and according to East Malling Quality Assurance (EMQA) procedures and requirements (experiment no. GEP12/008).

Results

Pre-assessment

In the pre-treatment assessment on 10 July the total numbers of mites and eggs on the 192 leaves was 307 motile mites, 667 eggs and no predatory mites (n=3 leaves/plot). The numbers of mites present were high but patchy across the plots. However, a decision was made to apply the treatments as the presence of eggs indicated that the mites had transferred to the experimental plants and were reproducing.

Tarsonemid assessments

Mean numbers of eggs generally increased in the untreated and Silwet treated plots over the course of the trail until the fourth assessment in the untreated plot when there were slightly fewer eggs in the folded leaves. Hence there was a significant effect of time (P <0.05, Table 4). There were also significant treatment effects (P <0.05, Table 4, Fig. 1). Of the 13 treatments and time combinations tested only four treatments significantly reduced the number of tarsonemid mite eggs (Figure 1), namely one or three sprays of Dynamc+Silwet L77, one spray of Masai+Silwet L77 or three sprays of the coded product HDC B004+Silwet L77. However, generally over the period of the trial numbers of eggs were also lower in the plots treated with one spray of Sequel+Silwet L77 also (Table 4).

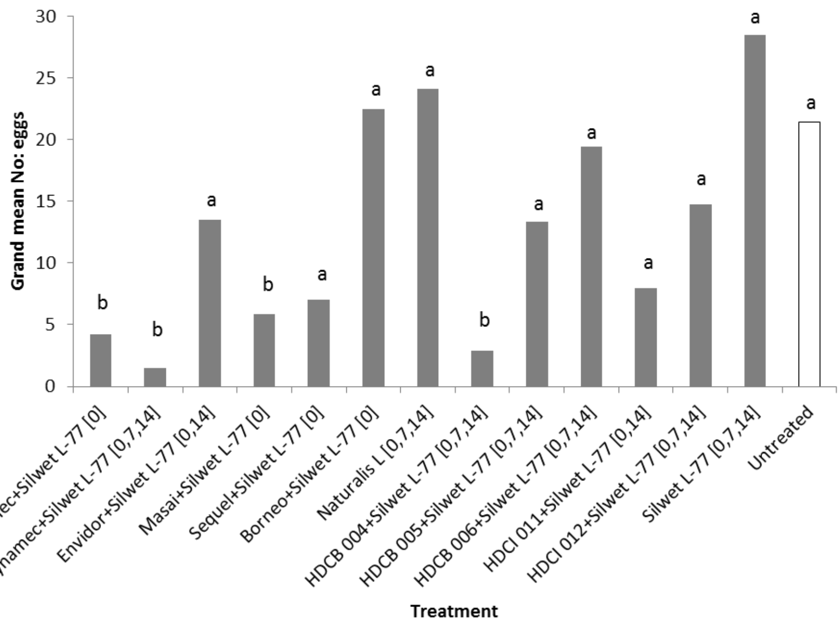


Figure 1. Grand mean numbers of tarsonemid mite eggs recorded on 10 trifoliate leaves/plot on each sampling date compared to the untreated control. Bars marked with the same letter do not differ significantly (p<0.05)

A very similar result was found for motile tarsonemid mites (adults and nymphs). One or three sprays of Dynamc+Silwet L77, one spray of Masai+Silwet L77 or three sprays of the coded product HDC B004+Silwet L77 reduced numbers in the folded leaves (P <0.05). One spray of Sequel+Silwet L77 also kept numbers down throughout the trial.

A final assessment (16 August) was done at the end of the trial on the product HDCB 007 and data for this product analysed separately. The numbers of tarsonemid mites on the treated plots were virtually identical to untreated plots and did not significantly reduce the grand means for the numbers of tarsonemid eggs and motile mites. These were 22.06 and 6.37 respectively for HDCB 007 compared to 19.53 and 7.00 respectively for the numbers of eggs and mites on the untreated control (Fig. 3).

Table 4. Mean and mean $Log_{10}(n+1)$ transformed numbers of tarsonemid eggs per 10 trifoliate leaves at day 4, 13, 19 and 25 after the first spray application of treatments on 13 July 2012, * = statistically significant

Treatment Product(s) [application timing]	**4 days**	**13 days**	**19 days**	**25 days**	**Grand mean**
Untransformed data (n=4)					
Dynamec+Silwet L-77 [0]	2.88	3.34	4.03	6.73	4.25
Dynamec+Silwet L-77 [0,7,14]	4.87	0.15	0.07	0.80	1.47
Envidor+Silwet L-77 [0,14]	3.25	9.30	20.09	21.42	13.52
Masai+Silwet L-77 [0]	4.55	1.85	7.28	9.63	5.83
Sequel+Silwet L-77 [0]	6.39	6.08	8.95	6.80	7.06
Borneo+Silwet L-77 [0]	8.93	24.82	25.80	30.23	22.45
Naturalis L [0,7,14]	16.87	9.90	43.80	25.77	24.09
HDCB 004+Silwet L-77 [0,7,14]	2.08	1.20	4.63	3.75	2.92
HDCB 005+Silwet L-77 [0,7,14]	4.04	11.08	23.43	14.70	13.31
HDCB 006+Silwet L-77 [0,7,14]	8.33	20.40	32.08	16.78	19.40
HDCI 011+Silwet L-77 [0,14]	6.18	12.57	6.75	6.40	7.98
HDCI 012+Silwet L-77 [0,7,14]	8.10	10.67	21.57	18.54	14.72
Silwet L-77 [0,7,14]	23.29	27.31	28.00	35.15	28.44
Untreated	18.25	16.65	28.72	22.11	21.43
Grand mean	8.43	11.09	18.23	15.63	13.35
	transformed data (n=4)				
Dynamec+Silwet L-77 [0]	0.480	0.385	0.519	0.852	*0.559
Dynamec+Silwet L-77 [0,7,14]	0.525	0.358	0.328	0.287	*0.375
Envidor+Silwet L-77 [0,14]	0.563	0.948	1.240	1.312	1.016
Masai+Silwet L-77 [0]	0.584	0.306	0.813	0.879	*0.646
Sequel+Silwet L-77 [0]	0.771	0.800	0.913	0.850	0.834
Borneo+Silwet L-77 [0]	0.935	1.422	1.408	1.436	1.300
Naturalis L [0,7,14]	0.873	0.946	1.464	1.340	1.156
HDCB 004+Silwet L-77 [0,7,14]	0.449	0.337	0.654	0.615	*0.514
HDCB 005+Silwet L-77 [0,7,14]	0.552	0.704	1.039	0.967	0.816
HDCB 006+Silwet L-77 [0,7,14]	0.886	1.262	1.464	1.186	1.200
HDCI 011+Silwet L-77 [0,14]	0.457	1.089	0.827	0.784	0.789
HDCI 012+Silwet L-77 [0,7,14]	0.792	0.979	1.281	1.266	1.080
Silwet L-77 [0,7,14]	1.059	1.127	1.352	1.413	1.238
Untreated	0.826	1.145	1.296	1.321	1.147
Grand mean	0.697	0.843	1.043	1.036	1.058

Anova Table *$Log_{10}(n+1)$*	Covariate	Treatment	Time	Treat.Time
Fprob	0.233	<.001	<.001	0.432
SED		0.192	0.058	0.271
df		38.000	83.230	106.420
LSD (P=0.05)		0.388[1]	0.124[2]	0.584[3]

1 For comparing grand means in column 6
2 For comparing grand means in row 15
3 For comparing means in the body of the table

Table 5. Mean and mean $Log_{10}(n+1)$ transformed numbers of motile tarsonemid mites per 10 trifoliate leaves at day 4,13,19 and 25 after the first spray application of treatments on 13 July 2012, * = statistically significant

Treatment Product(s) [application timing]	4 days	13 days	19 days	25 days	Grand mean
Untransformed data (n=4)					
Dynamec+Silwet L-77 [0]	2.05	1.46	1.58	2.63	1.93
Dynamec+Silwet L-77 [0,7,14]	1.72	1.12	0.08	1.13	1.01
Envidor+Silwet L-77 [0,14]	2.04	4.27	5.39	7.97	4.92
Masai+Silwet L-77 [0]	2.64	1.58	2.59	5.22	3.01
Sequel+Silwet L-77 [0]	2.57	3.00	4.06	3.28	3.23
Borneo+Silwet L-77 [0]	3.65	8.58	9.08	8.05	7.34
Naturalis L [0,7,14]	4.59	3.44	9.26	7.04	6.08
HDCB 004+Silwet L-77 [0,7,14]	1.81	0.78	1.18	1.43	1.30
HDCB 005+Silwet L-77 [0,7,14]	1.00	4.86	4.09	7.76	4.43
HDCB 006+Silwet L-77 [0,7,14]	2.04	7.84	8.06	5.96	5.97
HDCI 011+Silwet L-77 [0,14]	3.13	5.03	4.13	4.35	4.16
HDCI 012+Silwet L-77 [0,7,14]	5.01	5.88	6.36	8.69	6.49
Silwet L-77 [0,7,14]	5.69	8.06	8.55	9.25	7.89
Untreated	3.71	6.71	9.01	7.95	6.84
Grand mean	2.98	4.47	5.24	5.77	4.61
	Transformed data (n=4)				
Dynamec+Silwet L-77 [0]	0.407	0.257	0.298	0.523	*0.371
Dynamec+Silwet L-77 [0,7,14]	0.361	0.306	0.075	0.244	*0.246
Envidor+Silwet L-77 [0,14]	0.442	0.704	0.794	0.942	0.720
Masai+Silwet L-77 [0]	0.434	0.292	0.495	0.691	*0.478
Sequel+Silwet L-77 [0]	0.498	0.559	0.647	0.609	0.578
Borneo+Silwet L-77 [0]	0.597	0.976	0.958	0.958	0.872
Naturalis L [0,7,14]	0.648	0.631	0.925	0.848	0.763
HDCB 004+Silwet L-77 [0,7,14]	0.386	0.234	0.345	0.352	*0.329
HDCB 005+Silwet L-77 [0,7,14]	0.298	0.542	0.597	0.793	0.557
HDCB 006+Silwet L-77 [0,7,14]	0.454	0.874	0.890	0.827	0.761
HDCI 011+Silwet L-77 [0,14]	0.438	0.738	0.620	0.688	0.621
HDCI 012+Silwet L-77 [0,7,14]	0.612	0.766	0.786	0.976	0.785
Silwet L-77 [0,7,14]	0.719	0.823	0.906	0.954	0.850
Untreated	0.541	0.837	0.898	0.865	0.785
Grand mean	0.488	0.610	0.660	0.734	0.729

Anova Table (*$Log_{10}(n+1)$*)	Covariate	Treatment	Time	Treat.Time
Fprob	0.532	<.001	<.001	0.379
SED		0.114	0.042	89.510
Df		38.000	52.210	0.165
LSD (P=0.05)		0.230[1]	0.097[2]	0.382[3]

1 For comparing grand means in column 6
2 For comparing grand means in row 15
3 For comparing means in the body of the table

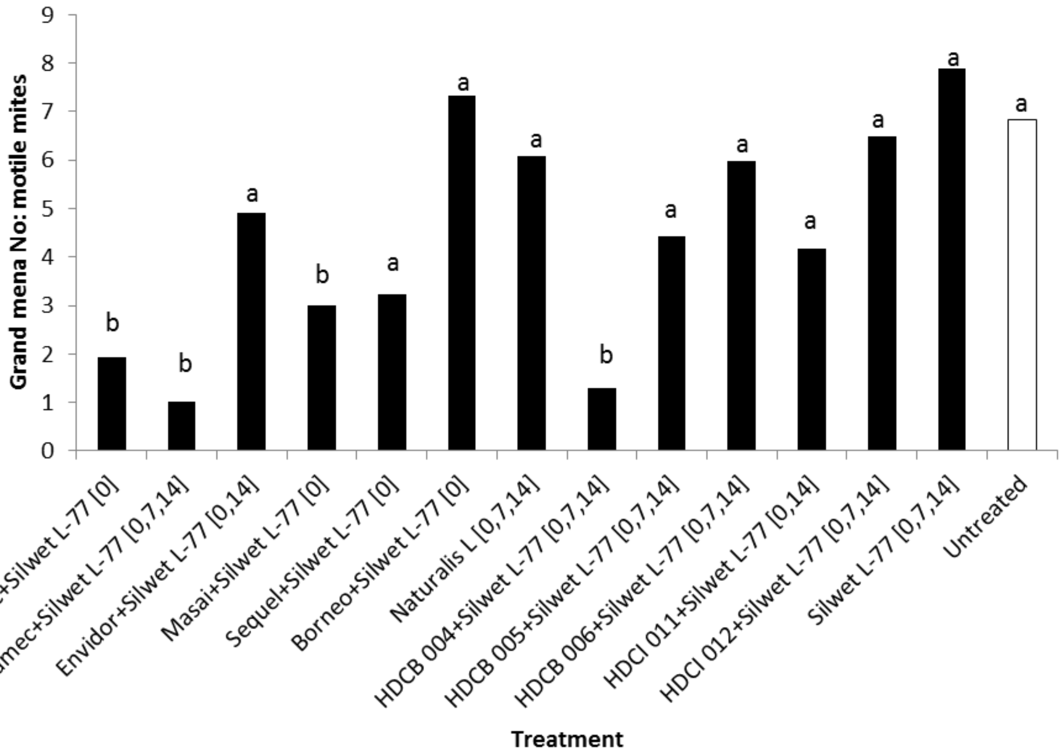


Figure 2. Grand mean numbers of motile tarsonemid mites recorded on 10 trifoliate leaves/plot on each sampling date compared to the untreated control

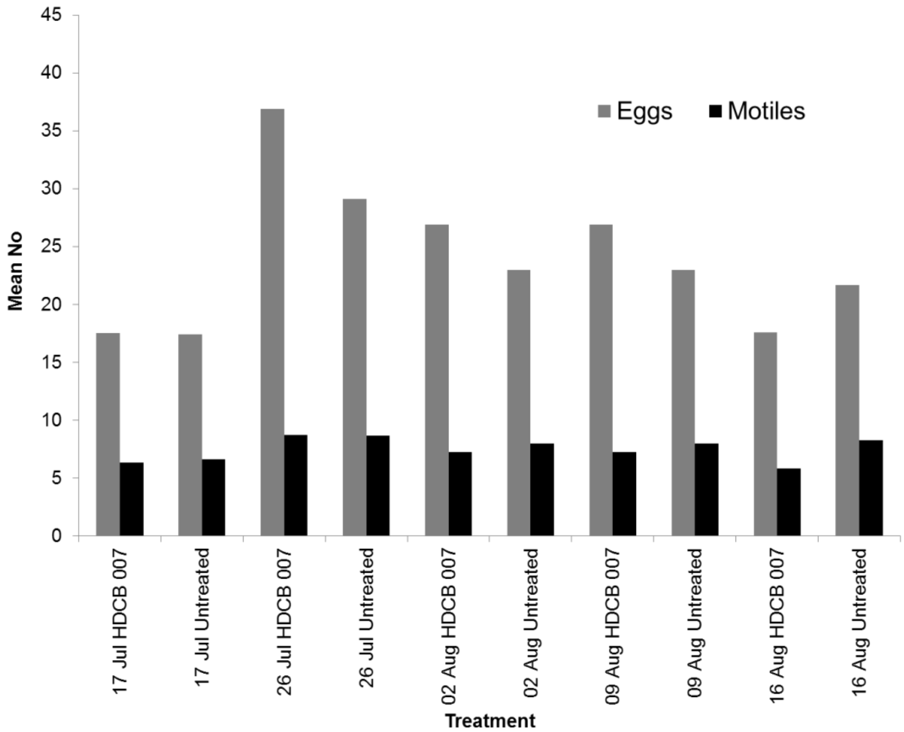


Figure 3. Mean numbers of tarsonemid mites (motiles and eggs) recorded on 10 trifoliate leaves/plot on each sampling date for HDCB 007 and the untreated control

Damage assessments

Score damage data for mite damage was angular transformed before ANOVA. No significant differences between any of the treatments and the untreated controls were visible (P = 0.104, Df = 46, SED = 3.103, LSD = 6.246, Fig. 4).

Damage to the foliage on some of the plots was noticed and so two assessments were made of the percentage of leaves affected (26 July and 9 August). This manifested as a red spotting of the leaves (Appendix 1), believed to be primarily caused by scorching after the products were applied. The data was angular transformed and analysed using ANOVA (Table 6). The data showed that for all the products and time combinations tested (including HDCB 007) three products showed significant levels of phytotoxicity (P <0.05, Appendix 1). There was also a significant effect of time, indicating that reddening was perceived to increase on most of the plots between the first and second assessments (P <0.05, Table 6).

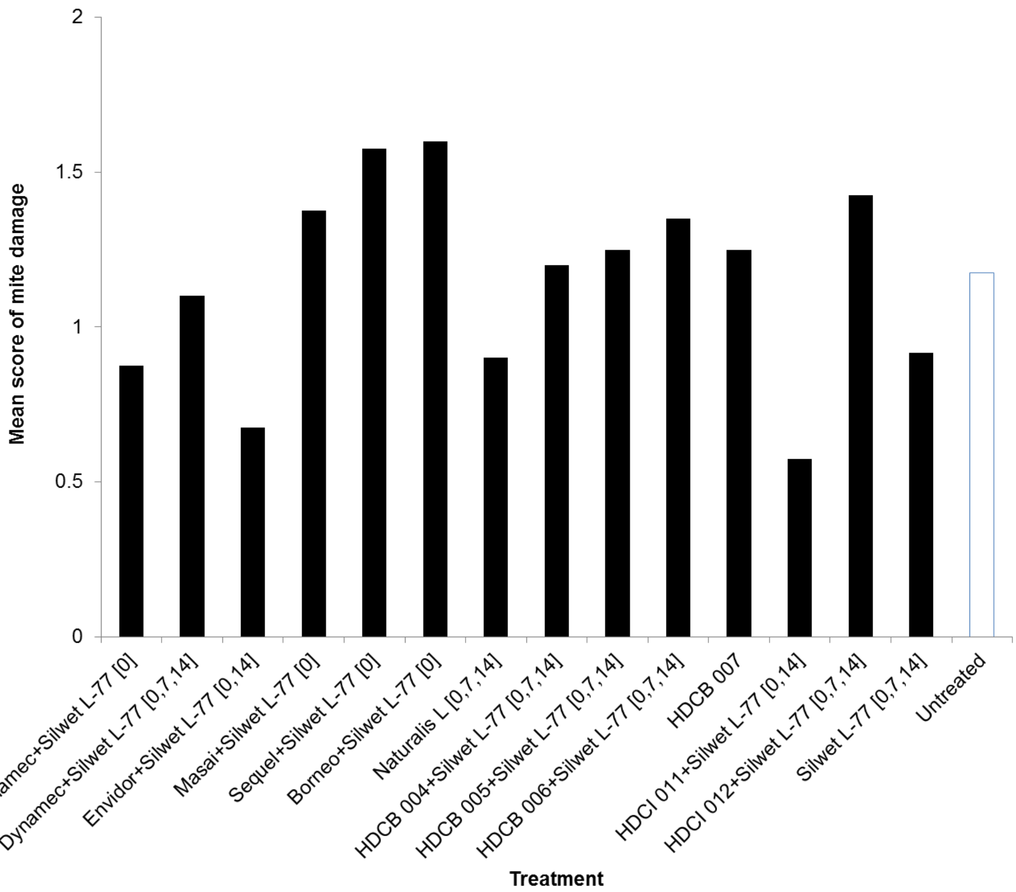


Figure 4. Mean tarsonemid mite damage score (0 = no Damage, 1 = slight damage, 2 = moderate damage, 3 = severe damage) per plot for each treatment

Table 6. Repeated measures ANOVA analyses on angular transformed data of the phytotoxic effects of treatment on leaves (% leaves reddened)

Treatment Product(s) [application timing]	26 July	9 August	Grand mean
Dynamec+Silwet L-77 [0]	0.50	3.50	2.00
Dynamec+Silwet L-77 [0,7,14]	1.50	4.50	3.00
Envidor+Silwet L-77 [0,14]	1.00	3.75	2.38
Masai+Silwet L-77 [0]	2.25	6.75	4.50
Sequel+Silwet L-77 [0]	0.50	3.75	2.13
Borneo+Silwet L-77 [0]	1.25	20.25	10.75
Naturalis L [0,7,14]	3.25	6.75	5.00
HDCB 004+Silwet L-77 [0,7,14]	0.50	3.50	2.00
HDCB 005+Silwet L-77 [0,7,14]	82.50	83.75	*83.13
HDCB 006+Silwet L-77 [0,7,14]	62.50	63.75	*63.13
HDCB 007 [0,7,14]	7.50	7.50	7.50
HDCI 011+Silwet L-77 [0,14]	0.00	1.25	0.63
HDCI 012+Silwet L-77 [0,7,14]	65.00	82.50	*73.75
Silwet L-77 [0,7,14]	0.50	4.25	2.38
Untreated	0.88	4.38	2.63
Anova Table	Treatment	Time	Treat.Time
Fprob	<.001	<.001	0.281
SED	4.270	1.268	5.281
df	42.000	49.000	79.210
LSD (P=0.05)	8.617	2.549	10.511

Discussion

Populations of tarsonemid mites developed sufficiently to show statistically significant differences between the treatments applied and the untreated control. The multiple infestations of the plots resulted in high mite populations. Four treatment/ time combinations were shown to reduce tarsonemid mites on strawberry. These were a single or three sprays of Dynamec+Silwet L-77, a single spray of Masai+Silwet L-77 or three sprays of the novel compound HDCB 004+Silwet L-77. There was no difference in efficacy between a single application of Dynamec+Silwet L-77 and three applications.

The single application of Sequel+Silwet L-77 was almost significant and may be a useful product combination to use in resistance management programmes as it offers a different mode of action and, if used in rotation with the other compounds, would help prevent a build-up of resistance to other effective acaricides.

Three of the novel coded products induced severe phytotoxic reactions in the strawberry plants. However none of these were efficacious against tarsonemid mites (but the phytotoxicity must be borne in mind if these products are used against other strawberry pests). Because tarsonemid damage persists in the older leaves long after the mites have been eradicated it was not possible to detect differences in mite damage between the treatments. However, this does highlight the importance of checking for mites and eggs, not just damage, when monitoring for the pest.

Conclusions

- A single spray of Dynamec+Silwet L-77, reduced the numbers of eggs by 80% and the number of motile mites by 72%.
- Three sprays of Dynamec+Silwet L-77, reduced the numbers of eggs by 93% and the number of motile mites by 85%.
- A single spray of Masai+Silwet L-77, reduced the numbers of eggs by 73% and the number of motile mites by 60%.
- Three sprays of HDCB 004+Silwet L-77, reduced the numbers of eggs by 86% and the number of motile mites by 81%.
- Dynamec, the positive control, is still the most effect of the commercially available products, although there was no significant difference between a single or three spray applications.
- A single application of Sequel+Silwet L-77, while not statistically significant, does reduce the numbers of eggs and the numbers of motile mites (67% and 53%, respectively). This could be used in conjunction with other treatments with different modes of action for resistance management programmes.
- HDCB 004 offered the most promise for future control of tarsonemid mite and is the highest priority for further investigation.
- The key to effective control with these products is good spray coverage with high water volumes.
- Growers should always aim to prevent the build-up of tarsonemid mites by using commercially available predatory mites introduced early in the season.
- Monitoring should include looking for mites and eggs, not just damaged leaves, as this may be old damage.

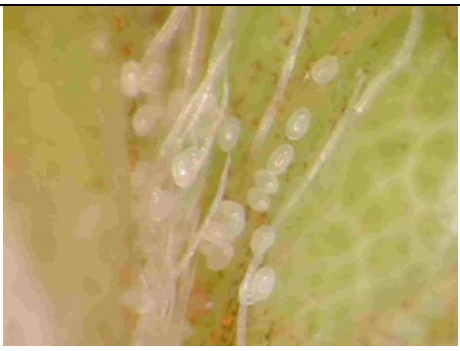
Future work

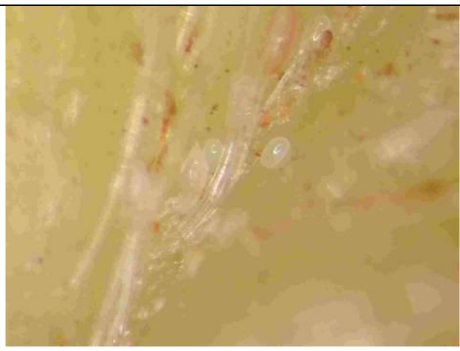
Further work is required on developing IPDM strategies for the control of tarsonemid mite and optimizing the timing of sprays. Sufficient data should be obtained to enable the approval of HDCB 004 for use on strawberry.

Acknowledgements

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, Antonio Llorente and Daniel Li of EMR, who assisted with the spraying, sampling and mite counts.

Appendix 1. Photographs from HDC strawberry trial 2012


Tarsonemid mite eggs


Tarsonemid mite eggs and nymph


Tarsonemid mite adult


Tarsonemid damage to strawberry leaf

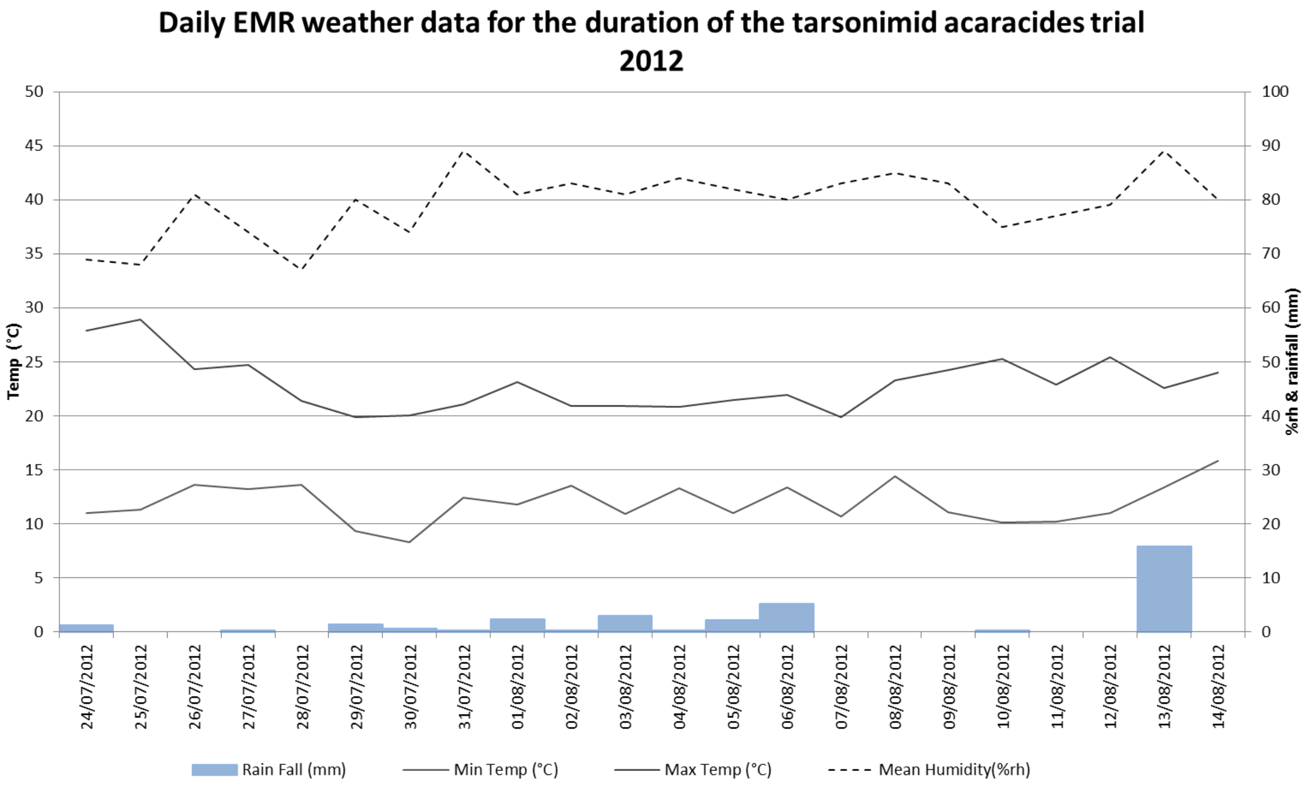

Polytunnel used in trial, 28 June 2012

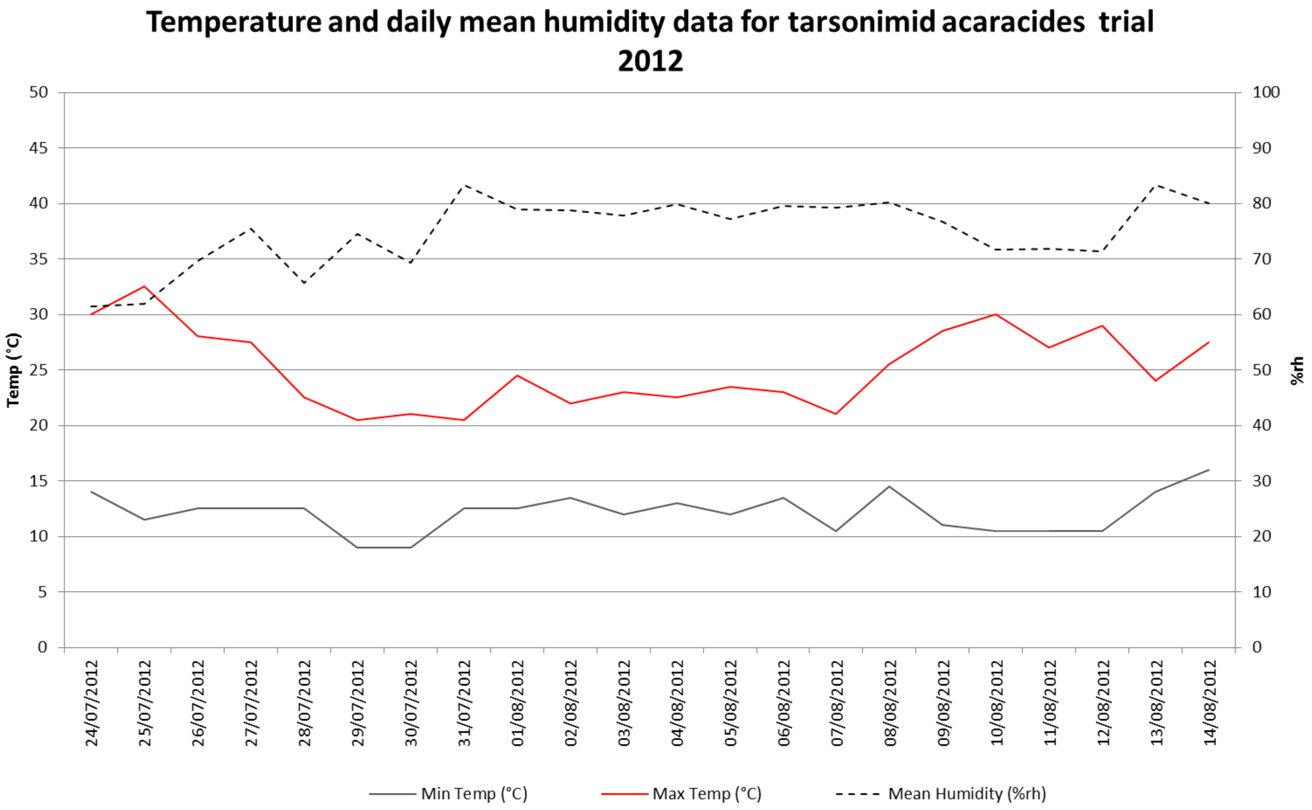

Plants in grow bags, 6 June 2011

Phytotoxicity recorded on 09 August 2012


Tarsonemid culture plants in glasshouse

Appendix 2


Daily EMR weather data for the duration of the tarsonimid acaracides trial 2012
Temp (°C)
%rh & rainfall (mm)
0
5
10
15
20
25
30
35
40
45
50
0
10
20
30
40
50
60
70
80
90
100
24/07/2012
25/07/2012
26/07/2012
27/07/2012
28/07/2012
29/07/2012
30/07/2012
31/07/2012
01/08/2012
02/08/2012
03/08/2012
04/08/2012
05/08/2012
06/08/2012
07/08/2012
08/08/2012
09/08/2012
10/08/2012
11/08/2012
12/08/2012
13/08/2012
14/08/2012
Rain Fall (mm)
Min Temp (°C)
Max Temp (°C)
Mean Humidity(%rh)


Temperature and daily mean humidity data for tarsonimid acaracides trial 2012
Temp (°C)
%rh
0
5
10
15
20
25
30
35
40
45
50
0
10
20
30
40
50
60
70
80
90
100
24/07/2012
25/07/2012
26/07/2012
27/07/2012
28/07/2012
29/07/2012
30/07/2012
31/07/2012
01/08/2012
02/08/2012
03/08/2012
04/08/2012
05/08/2012
06/08/2012
07/08/2012
08/08/2012
09/08/2012
10/08/2012
11/08/2012
12/08/2012
13/08/2012
14/08/2012
Min Temp (°C)
Max Temp (°C)
Mean Humidity (%rh)