NOVEL CHEMICALS TO CONTROL SIX-SPOTTED MITE, *EOTETRANYCHUS SEXMACULATUS*

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ABSTRACT

Six-spotted mite (6SM) *Eotetranychus sexmaculatus* (Acari:Tetranychidae) is a major pest of avocados in New Zealand, especially in more northern regions. Extensive leaf drop is reported from 6SM infestations. A small-plot field trial was undertaken. Two sprays of either abamectin (Avid) or milbectin (Mit-é-mec) applied with 0.5% mineral oil (Yates Excel) very significantly reduced mite numbers, and these remained less than the untreated control for at least 9 weeks. None of the other products tested, GC Mite (clove oil, garlic and cottonseed oil), Myco-Force (fungal insect pathogens *Verticillium lecani, Metarhizium anisopliae,* and *Beauvaria bassiana*), Neem Azal T/S (neem oil), sucrose octanoate and Thiodan (endosulfan) showed any effect. Observations on biological control agents and tydeid mites are included.

Keywords: six-spotted mite, control, abamectin, milbemectin, tydeids, predators

INTRODUCTION

Six-spotted mite (6SM) *Eotetranychus sexmaculatus* (Riley)(Acari:Tetranychidae) has been present in New Zealand since the 1950s, but has only recently become a serious problem in avocado orchards (Stevens, 2001). Infestations of 6SM are attributed with causing serious defoliation of avocado trees, with a consequential impact on productivity. The problem this pest poses is heightened because no chemicals are currently registered for its control in New Zealand, and market requirements severely restrict the range of pesticides that can be used on export avocados. Two mectin products, Avid (abamectin) and Mit-é-mec (milbemectin), are in the process of obtaining registration[1]. The former chemical is used on avocados in California under a dispensation system against several mite species, including 6SM. Some organophosphate chemicals that are registered in New Zealand for use against other pests on this crop have shown activity against 6SM. However, their continued effectiveness is problematic, and consumer concerns are likely to restrict if not abolish their use in the near future.

Several importers of novel materials that fit GRAS (generally recognised as safe) criteria, and so can be exempted from undergoing the full registration process, claim that these materials are active against mites. Four of these were tested in the current trial, which also included a chemical used in Australia on avocados that has some mite activity. Both mectin products were included as standards in order to obtain a direct comparison of them.

[1] Avid is now registered.

METHODS

The trial was conducted on a block of young avocado trees, 1.2 - 2 m tall, near Kaitaia in the Far North. The variety was Hass with Reed as a pollinator. Single tree plots were used, with five replicates in a randomised block design. The seven spray treatments (Table 1) were applied twice, 14 days apart (27 November 2002 and 14 December 2002), in high volume sprays to run-off using a Solo mistblower.

Table 1. The treatments applied.

Treatment	Product [1]	containing	Rate of product ml / 100 L
1	SO	sucrose octanoate, a sugar ester	1000
2	GC Mite [2]	clove oil 20%, garlic extract 10%, cottonseed oil 40%, inert 30%	1000
3	Neem Azal T/S	neem oil, including azadirachtin @ 10g/L	500
4	EF Myco-Force	3 entomopathogenic fungi [3]	25 g
5	Thiodan 35 EC	endosulfan, 350 g/L	200
6	Avid + 0.5% oil [4]	abamectin, 18 g/L	37.5 + 500
7	Mit-é-mec + 0.5% oil [4]	milbemectin, 9.3 g/L	75 + 500
8	untreated control	--	-

[1] = all products other than the mectins had the non-ionic wetter Contact added at 25 ml / 100 L
[2] = GC Mite has had several formulations, this was batch 2107011
[3] = *Verticillium lecani, Metarhizium anisopliae,* and *Beauvaria bassiana*, total $3*10^6$ spores / g
[4] = Yates Excel Oil

Mite numbers on leaves were assessed using a stereomicroscope. A pre-spray check used a score of adults plus immature stages on each leaf to confirm that the site was suitable. At intervals after the second spray leaves were picked and the mites present on each leaf as adults, immature stages or eggs were counted separately. A factorial scoring system was used to transform the counts for each leaf before analysis:-

Scores					
	0 = 0	2 = 2, 3	4 = 8 – 15	6 = 32 – 63	8 = ≥ 128
	1 = 1	3 = 4 – 7	5 = 16 – 31	7 = 64 – 127	

Results were analysed using the GLM analysis of variance (anova) model in Systat 9. Percentage data were transformed to arc-sine values for analysis, but all means shown are derived from raw figures. Means were compared using Tukey's HSD test, and significance testing used the 5% and 1% probability levels, shown by lower and upper case letters respectively. Tabled means in the same column are significantly different if they do not have a letter in common.

RESULTS AND DISCUSSION

Pre-spray

Samples of five old leaves per plot were picked. When half the samples had been scored results showed that mite numbers were high and variable, with one or more active mite on 82 % of the leaves and a median score of 4 per leaf (= 8-15 mites /leaf). Since there was no clear pattern of mite numbers across the site the trial proceeded as planned, with each replicate basically in a separate row.

However, when all the results were analysed it was found that the treatment with the lowest mean score per plot was the untreated control, and this was significantly less than the highest treatment (for Myco-Force) (Table 2). This slight imbalance before the trial began is unlikely to have affected the outcome.

Table 2. The average score per 10 leaves and percent of leaves infested with 6SM before the trial began.

Treatment	Score / 10 leaves		% leaves infested
SO	24.4	ab	68
GC Mite	39.6	ab	80
Neem Azal T/S	34.0	ab	88
Myco-Force	50.4	a	100
Thiodan	40.0	ab	92
Avid + 0.5% oil	34.0	ab	84
Mit-é-mec + 0.5% oil	43.6	ab	96
untreated control	18.0	b	64
overall average	35.5		*84*

Means were compared using Tukey's HSD test, and significance testing used the 5% and 1% probability levels, shown by lower and upper case letters respectively. Tabled means in the same column are significantly different if they do not have a letter in common.

Post-spray sample 1

On 28 December, 17 days after the second spray had been applied, 10 new growth leaves were assessed for each plot. The average total number of mites (for all stages combined) per 10 leaves was very high and only the two mectin products, Avid and Mit-é-mec, showed any impact in this assessment (Table 3). Both these products were highly effective, with no difference between them. Both also gave a highly significant ($p<0.01$) reduction in the percentage of leaves infested.

Table 3. Mite populations and infestation levels on 28 December 2002, 17 days after two sprays had been applied.

Treatment	Number of mites / 10 leaves		% leaves infested	
SO	265	b B	89	b B
GC Mite	428	b B	86	b B
Neem Azal T/S	571	b B	96	b B
Myco-Force	605	b B	97	b B
Thiodan	261	b B	96	b B
Avid + 0.5% oil	3	a A	16	a A
Mit-é-mec + 0.5% oil	4	a A	13	a A
untreated control	372	b B	87	b B

Means were compared using Tukey's HSD test, and significance testing used the 5% and 1% probability levels, shown by lower and upper case letters respectively. Tabled means in the same column are significantly different if they do not have a letter in common.

The plots in the outermost row of the block produced some unusually low values compared to the same three treatments in other replicates. However, excluding this replicate from the analysis did not alter the pattern of significance obtained and so it was included.

The results for each developmental stage of 6-spotted mite were examined separately to see if the population structure had been affected by any treatment (Table 4). These results emphasise that only the mectins were effective, and reduced all stages.

Table 4. Average number of each stage of 6SM per 10 leaf sample on 28 December 2002.

Treatment	Numbers per 10 leaf sample adult		immature		egg	
SO	18	ab	118	b B	130	b B
GC Mite	36	ab	211	b B	181	b AB
Neem Azal T/S	40	ab	262	b B	270	b B
Myco-Force	48	b	303	b B	254	b B
Thiodan	22	ab	122	b B	117	b B
Avid + 0.5% oil	0.7	a	0.0	a A	2.2	a A
Mit-é-mec + 0.5% oil	0.3	a	2.7	a A	1.0	a A
untreated control	24	ab	155	b B	194	b B

Means were compared using Tukey's HSD test, and significance testing used the 5% and 1% probability levels, shown by lower and upper case letters respectively. Tabled means in the same column are significantly different if they do not have a letter in common.

The proportion of 6SM in each developmental stage was calculated (Table 5). This shows that both the mectin products altered the age structure of the populations sampled, although the small number of mites in each of these two treatments makes any definite interpretation uncertain. The age structure in all other spray treatments and the untreated control showed an extremely similar pattern, which further indicates that none of these novel compounds had any effect on 6SM. The Avid plots contained only adults and eggs, which could reflect recent immigration. However, the Mit-é-mec plots had fewer eggs than untreated and more immature mites. This difference between Avid and Mit-é-mec probably was due to the very few mites present.

Table 5. Relative proportions in each mite stage, and sample size on 28 December 2002.

Treatment	Percent in each stage adult	immature	egg	Sample size
SO	7	44	49	1713
GC-Mite	9	46	44	2833
Neem Azal T/S	7	46	47	2984
Myco-Force	8	51	41	3463
Thiodan	9	48	43	1652
Avid + 0.5% oil	26	0	74	19
Mit-é-mec + 0.5% oil	9	68	23	22
untreated	7	42	51	2148

Post-sprays sample 2

A second sample was taken 36 days after the second sprays had been applied. For the untreated control and the two promising materials 20 leaves per plot were assessed for all five replicates, while for the remaining five treatments, five leaves per plot were assessed for just two replicates. The novel materials were re-assessed simply in case a delayed response had occurred. None was apparent.

The two effective materials continued to have very low numbers of mites present, with high numbers in all other treatments (Table 6). The untreated result for the two replicates in which all treatments were assessed is also shown to give a direct comparison with the novel materials. The average for untreated and ineffective materials was 24 mites per leaf for all stages of 6SM combined while the two mectin compounds each had one mite or less per leaf.

Table 6. The average number of all stages of 6SM combined and percentage of leaves infested, 36 days after the second spray in January 2003.

Treatment	Number of mites / 10 leaves		% leaves infested	
SO	261		90	
GC-Mite	259		100	
Neem Azal T/S	227		100	
Myco-Force	264		100	
Thiodan	238		100	
untreated (2 replicates)	239		100	
Avid + 0.5% oil	10	a A	21	a A
Mit-é-mec + 0.5% oil	6	a A	24	a A
untreated	208	b B	92	b B

Only the 3 treatments assessed over all 5 replicates were analysed. Means were compared using Tukey's HSD test, and significance testing used the 5% and 1% probability levels, shown by lower and upper case letters respectively. Tabled means in the same column are significantly different if they do not have a letter in common.

The reduction in total numbers of mites by the mectin treatments reflected a reduction in each life stage recorded. Both mectins gave similar results, so a combined result is given for the age structure of mites in the sample (Table 7). The results for the ineffective treatments were also combined, and again closely parallel the proportions in the untreated. There were fewer immature mites on trees sprayed with a mectin, and comparatively more adults and eggs. This may reflect immigration of adults onto such sprayed trees, together with an increased mortality of the resultant immature stages due to persistent residues that do not affect eggs.

Table 7. Relative proportions in each mite stage, and sample size, January 2003.

Treatment	Percent in each stage: adult	immature	eggs	Sample size
mectins	11	20	69	167
other sprays	7	34	60	1249
untreated	7	32	61	2081

Post-sprays sample 3

A further 20-leaf sample was taken for both the mectins and the untreated controls on 13 February, 64 days after the second sprays had been applied. Populations of 6SM in the unsprayed plots had decreased markedly since the previous sample, while they had risen in the plots treated with mectins (Table 8 cf Table 6). The variability among plots sprayed with the same treatment was high. Thus, although there was a clear pattern showing a residual effect of the mectin sprays, the differences among treatments approached, but did not reach, being statistically significant.

Table 8. The average number of all stages of 6SM combined and the percentage of leaves infested in February 2003, 64 days after two sprays.

Treatment	Number of mites / 10 leaves	% leaves infested
Avid + 0.5% oil	19.1	31.0
Mit-é-mec + 0.5% oil	23.0	46.0
untreated	55.7	65.0

The age structure of the mite population in each treatment no longer showed a clear or consistent affect from the mectins (Table 9 cf Table 7). The Avid result tended to the pattern shown by both mectin products in earlier samples, while that for Mit-é-mec was more similar to the pattern in untreated.

Table 9. Relative proportions in each mite stage in February 2003, and sample size.

Treatment	Percent in each stage			Sample size
	adult	immature	egg	
Avid + 0.5% oil	12	18	70	191
Mit-é-mec + 0.5% oil	9	25	66	231
untreated	9	27	64	557

Potential predators

In the pre-trial sample 25 live *Stethorus* larvae were found, on nine leaves (4.5% of leaves were occupied by these ladybird larvae). Only a single predator mite was found, tentatively identified as from the family Agistemidae.

In the December sample *Stethorus* was still by far the most numerous predator found on the avocado leaves. There were 32 live larvae or pupae (5.3% of leaves occupied). On four occasions predation of 6SM by a *Stethorus* larva was actually seen, with the prey being once an adult mite, twice being immature mites and once an egg. Only three phytoseid and five agistemid predator mites (juveniles) were seen, with 0.5% and 1.0% of leaves occupied, respectively.

The incidence of *Stethorus* was lower in the mid-January sample at 3.4% of leaves occupied, but this would be partly due to focussing the sampling on the plots sprayed by either Avid or Mit-é-mec. However, there was also a shift to finding far more shed skins than live larvae and pupae (25 skins v. 5 live insects). The increasing incidence of shed skins compared to earlier samples shows a changing population structure for the predatory ladybird. Numbers of predator mites remained low with only four phytoseid and two agistemid mites found (0.8% and 1.0% of leaves occupied, respectively).

When the final sample was collected in the middle of February, the incidence of *Stethorus* was even lower (1.0% of leaves occupied by live *Stethorus*, with three live insects and six cast skins found). In contrast, the numbers of predator mites had risen considerably to 19 phytoseids and five agistemids (occupying 5.7% and 1.0% of leaves respectively).

Tydeid mites

The tydeid mites *Orthotydeus californicus* and *O. caudatus* are commonly found on a number of tree crops in New Zealand. Although some authors have considered them to be predatory, tydeid mites are now believed to feed on fungi and detritus. Large numbers can occur on avocado leaves, where they tend to occupy the same sites as 6SM. Tydeids may provide an alternative food for predators that feed on pest species such as 6SM. It is difficult to separate the young stages of these tydeid species from 6SM, which is a point that pest scouts must keep in mind.

At this site tydeids were not particularly numerous, but increased over time (Table 10). As the trees sampled each time did vary, and mite populations can vary from tree to tree, this shows the results just for those trees sampled on each occasion.

Table 10. The tydeid population on trees sampled on each occasion.

	Sample date			
	27 Nov	28 Dec	16 Jan	13 Feb
No of tydeids	0	3	27	81
% leaves infested	0	1.3	6.3	13.7
No of leaves sampled	*75*	*180*	*300*	*300*

CONCLUSIONS

The two standard mectin treatments, Avid and Mit-é-mec, both showed outstanding effectiveness in reducing 6SM populations, and in maintaining a long-lasting reduction, with an effect still being apparent after 9 weeks. There was no difference between the two related products. Two sprays (with 0.5% oil), in late November and 14 days later, reduced mite numbers on treated avocado trees through to mid-February, by when populations were declining naturally. Mite numbers were high when the first sprays were applied, so that the timing of the trial was later than would be ideal to prevent damage. However, numbers in the untreated control plots were highest at the end of December, and then declined naturally, so that spraying at the time it was done did prevent peak populations developing.

None of the other treatments tested showed any sign of reducing an established population of 6SM, under the conditions used. Note that mycopathogens (as in Myco-Force) often require periods of high humidity or free moisture to be effective, but that such conditions are likely to give plant damage for sprays such as GC Mite or oils. Although some fungi can effectively reduce mite numbers, the species present in Myco-Force are better known for killing insects. It is possible that some of the novel products tested could act as a preventative if applied before the population developed, but the lack of any apparent effect in this trial is not promising.

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