MITICIDES AGAINST CITRUS RED MITES (*PANONYCHUS CITRI*)

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ABSTRACT

Citrus red mite (CRM), *Panonychus citri*, is only a significant pest of citrus in New Zealand when the broad-spectrum activity of insecticides targeting other key pests disrupts the activity of its natural enemies. The long-term solution to CRM control is to eliminate the use of disruptive agrichemicals, but until this happens effective miticides are needed to control CRM. Two small-plot field trials were conducted in 2004 and 2005 in a lemon orchard in Kerikeri. In the first trial, two applications of milbemectin, abamectin, fenpyroximate or propargite were effective against eggs and motile life stages. Oil at 1% was not as effective as milbemectin at suppressing the incidence of eggs on leaves 6 weeks after application, but was more effective than a 0.5% rate. In the second trial the *Stethorus* sp. ladybird and *Agistemus longisetus* predatory mite reduced CRM populations in both unsprayed trees and trees treated with miticides. **Keywords:** *Panonychus citri*, citrus red mite, miticides, spray trial.

INTRODUCTION

Citrus red mite (CRM) (*Panonychus citri*) is one of the key pests of citrus in New Zealand (Pyle & Stevens 2004) and is present in nearly all areas of the world where citrus is grown (CABI 2004). Nymphs and adults extract nutrients from the host tissue using their piercing, suckling mouthparts. This feeding produces tiny grey or silvery spots on leaves and fruit (stippling). Damage to leaves inhibits photosynthesis, increases transpiration and can lead to necrosis. Severe infestations can lead to premature leaf fall, dieback and decreased vigour (Kranz 1977).

CRM is typically considered a 'pesticide induced' pest in New Zealand citrus (Pyle & Stevens 2004). Populations may increase dramatically in an orchard following application of broad-spectrum insecticides to control other major pests, particularly Kelly's citrus thrips (*Pezothrips kellyanus*) and citrus flower moth (*Prays nephelomima*). It is thought that these chemicals disrupt the activity of CRM natural enemies, especially the coccinellid ladybird, *Stethorus* sp. and the stigmatid mite *Agistemus longisetus* (Jamieson et al. 2005, 2008). The long-term solution to CRM management is to eliminate the use of agrichemicals that disrupt the activity of its natural enemies. However, until such solutions are devised effective miticides will be needed to control CRM outbreaks in orchards. The primary aim of this research was to evaluate a range of miticide products for use in CRM management.

METHODS

Trial 1

A small-plot field trial comparing the efficacy of six miticide treatments against CRM was carried out in a Kerikeri lemon orchard (9 year old 'Yen Ben' trees, 4 m tall) between March and May 2004. Each of seven treatments was applied to single-tree plots that were allocated in a randomised block design with five replicates of each treatment. Treatments were numbers 1-6 in Table 1 and an untreated control. All treatment trees were surrounded by unsprayed buffer trees on all sides to prevent spray contamination between treatments.

Treatments were applied to drip formation/run-off using a motorised sprayer and a single nozzle handgun at 1680-1720 litres/ha. Two applications of each treatment were made, with a 2-week interval between them, on 23 March and 6 April 2004.

Prior to the first application, a sample of 20 leaves per plot was collected and placed in plastic MinigripTM bags. Because all leaves were heavily infested prior to treatment, leaf samples were brushed using a mite brusher and the number of eggs, juveniles and adult CRM were counted. Before the second application, and 3 and 6 weeks afterwards, 20 leaves per tree were collected and the numbers of eggs, juvenile and adult mites were assessed for each leaf under a microscope. Twenty fruit per tree were also examined at the same times, *in situ* using a 10X hand-lens, and the numbers of live mites (juveniles and adults) were counted. Live mites included those in their quiescent, pre-moult state. Results from sprayed trees were compared with those from unsprayed trees.

Trial 2

A similar trial was conducted in the same lemon block as trial 1 from February to April 2005. Treatments were number 4-8 in Table 1 and an untreated control. Two sprays were applied with a 2-week interval between, except for clofentezine-treated trees, which were sprayed once.

Before the first and second spray application and 3 and 6 weeks after the second spray application, 10 fruit per tree were examined *in situ* using a 10X hand-lens. The numbers of live CRM (juveniles and adults) were counted and the presence of CRM eggs recorded. At the same time a sample of 10 leaves was collected as above. Each leaf was scanned under 10X magnification and the numbers of CRM eggs, juveniles and adults was recorded, as well as the number of predatory mites and *Stethorus* ladybirds. Evidence of the previous presence of *Stethorus* (larval moults, pupal cases and egg cases) was also recorded.

TABLE 1: The active ingredient, chemical group, trade name, rates and New Zealand distributor of agrichemicals used in trials 1 and 2.

Treatment number	Active ingredient and rate	Chemical group	Trade name and application rate	New Zealand distributor
1	Mineral oil (991 ml/litre)	Mineral oil	0.5% DC-Tron NR	PGG Wrightson Limited
2	Mineral oil (991 ml/litre)	Mineral oil	1% DC-Tron NR	PGG Wrightson Limited
3	Fenpyroximate (50 g/litre)	Phenoxy pyrazole	Fenamite 50 ml/100 litre	Dow AgroSciences (NZ) Ltd
4	Milbemectin (9.3 g/litre)	Avermectin	Mit e' mec [®] 75 ml/100 litre + Contact Low Foam 12.5 ml/100 litre	Fruitfed Supplies
5	Propargite (300 g/kg)	Sulphur compound	Omite [®] 30W 200 g/100 litre	Nufarm NZ Ltd
6	Abamectin (18 g/litre) + mineral oil	Avermectin	Avid [®] 25 ml/100 litre + 0.5% DC Tron NR oil	Syngenta Crop Protection
7	Abamectin (18 g/litre) + mineral oil	Avermectin	Avid [®] 37.5 ml/100 litre + 0.5% DC Tron NR oil	Syngenta Crop Protection
8	Clofentezine (500 g/litre)	Tetrazine	Apollo [®] 50 SC 40 ml/100 litre + 0.5% DC Tron NR oil	Elliott Technologies

The numbers of eggs, juvenile and adult mites per leaf or fruit were compared between treatments using a randomised block design analysis of variance (ANOVA). Percentages of leaves or fruits infested were first angular transformed and then analysed similarly using ANOVA, but untransformed percentages are presented in tables. Least significant differences (LSDs) were calculated to separate treatments if the ANOVA resulted in $P < 0.05$. The analysis was performed using the GenStat statistics programme (Release 7.2).

RESULTS

Trial 1 – CRM on leaves

Before the first miticide application there were no significant differences between the mean number of eggs (51-70 per leaf), juveniles (13-15 per leaf) or adults (4-5 per leaf) on leaves collected from any of the trees.

After the first spray application all miticide treatments had significantly reduced the incidence (percentage of leaves infested) and severity (number per leaf) of egg and mite infestations compared with unsprayed leaves (Table 2).

Three weeks after the second spray the average of number of eggs per leaf on miticide-treated trees had decreased further to an average of 0.08-0.73 eggs and 0-0.05 mites per leaf compared to 27.49 eggs and 9.32 mites on unsprayed leaves.

Six weeks after the second spray application the incidence of CRM eggs and other stages on leaves had increased slightly. Trees treated with milbemectin, fenpyroximate, abamectin and propargite had 3-17% of leaves infested with eggs and 3-6% infested with mites. Trees treated with mineral oil had an intermediate incidence while unsprayed trees had 100% of leaves infested with eggs and 98% infested with mites.

Trial 1 – CRM on fruit

After the first spray application all miticide treatments had significantly reduced the incidence (percentage of fruit infested) and severity (number per fruit) of mites on fruit compared with those on unsprayed fruit (Table 3). Although abamectin and propargite (5% of fruit infested) tended to have lower infestation than fenpyroximate and milbemectin (13-17% of fruit infested), these four treatments did not differ significantly (Table 3). Trees treated with either of the mineral oil treatments had an average of 55-76% of fruit infested with mites and 100% of untreated fruit were infested.

Three weeks after the second spray, infestations of CRM on fruit had decreased further. No juvenile or adult mites were found on fruit sprayed with abamectin and milbemectin, and 2.7-6.7% of fruit on fenpyroximate and propargite treated trees were infested (Table 3). Trees treated with either of the mineral oil treatments had 17-33% of fruit infested, which was significantly lower than the unsprayed trees with 100% of fruit infested.

Six weeks after the second application, trees treated with either abamectin, fenpyroximate, milbemectin, propargite or 1% mineral oil had 0-6.7% of fruit infested with mites, which was significantly less than trees treated with 0.5% mineral oil (24% of fruit infested) (Table 3). At this time 96% of fruit on untreated trees were infested with mites.

Trial 2 – CRM infestations

A high level of predatory activity in the block resulted in the population of CRM declining on both the treated trees and the control trees over the period of the trial (Table 4). There was an average of ca 90% of leaves infested with ca 15 CRM eggs and 15 mites per leaf at the beginning of this trial. Two weeks after the first spray application, milbemectin- and propargite-treated trees had significantly fewer fruit infested with CRM eggs (10-20%) than untreated trees (70% fruit infested); while trees treated with abamectin, milbemectin and clofentezine had significantly fewer fruit infested with juvenile and adult mites than untreated and propargite-treated trees. Three weeks after the second application, the CRM population had declined to low levels in all trees due to the high level of predatory activity in the block.

TABLE 2: Mean number of eggs per leaf and live CRM (juveniles plus adults) per leaf and the percentage of leaves infested with eggs or live CRM for each treatment in Trial 1. Values are the treatment mean $\pm$ SEM.

Treatment	Eggs	Live CRM	% leaves with eggs	% leaves with live CRM
Pre spray 2				
0.5% oil	8.46 $\pm$ 2.77 b ¹	0.20 $\pm$ 0.10 b	81.0 $\pm$ 5.8 ab	14.0 $\pm$ 4.9 b
1% oil	4.80 $\pm$ 1.68 b	0.20 $\pm$ 0.15 b	69.0 $\pm$ 12.7 b	12.0 $\pm$ 8.5 bc
milbemectin	4.34 $\pm$ 1.67 b	0.14 $\pm$ 0.11 b	57.0 $\pm$ 11.3 b	8.0 $\pm$ 5.8 bc
fenpyroximate	2.50 $\pm$ 0.61 b	0 b	55.0 $\pm$ 8.5 b	0 c
abamectin	2.37 $\pm$ 0.39 b	0.01 $\pm$ 0.01 b	65.0 $\pm$ 6.7 b	1.0 $\pm$ 1.0 bc
propargite	3.86 $\pm$ 1.19 b	0.07 $\pm$ 0.04 b	68.0 $\pm$ 10.2 b	3.0 $\pm$ 1.2 bc
untreated	29.36 $\pm$ 3.94 a	4.60 $\pm$ 0.76 a	100 a	86.0 $\pm$ 1.9 a
P-value	<0.001	<0.001	0.001	<0.001
3 weeks after spray 2				
0.5% oil	0.73 $\pm$ 0.31 b	0.02 $\pm$ 0.01b	22.0 $\pm$ 9.2 b	2.0 $\pm$ 1.2 b
1% oil	0.22 $\pm$ 0.16 b	0 b	12.0 $\pm$ 7.5 b	0 b
milbemectin	0.08 $\pm$ 0.06 b	0.05 $\pm$ 0.04 b	5.0 $\pm$ 3.9 b	3.0 $\pm$ 2.0 b
fenpyroximate	0.16 $\pm$ 0.08 b	0 b	8.0 $\pm$ 3.0 b	0 b
abamectin	0.26 $\pm$ 0.13 b	0 b	13.0 $\pm$ 5.6 b	0 b
propargite	0.16 $\pm$ 0.10 b	0 b	9.0 $\pm$ 5.6 b	0 b
untreated	27.49 $\pm$ 6.67 a	9.32 $\pm$ 2.952 a	98.0 $\pm$ 2.0 a	86.0 $\pm$ 8.6 a
P-value	<0.001	<0.001	<0.001	<0.001
6 weeks after spray 2				
0.5% oil	1.38 $\pm$ 0.22 b	0.24 $\pm$ 0.03 b	49.0 $\pm$ 6.6 b	20.0 $\pm$ 2.7 b
1% oil	0.80 $\pm$ 0.24 b	0.21 $\pm$ 0.07 b	33.0 $\pm$ 8.2 bc	18.0 $\pm$ 5.8 b
milbemectin	0.05 $\pm$ 0.03 b	0.06 $\pm$ 0.02 b	3.0 $\pm$ 2.0 d	6.0 $\pm$ 1.9 bc
fenpyroximate	0.29 $\pm$ 0.08 b	0.03 $\pm$ 0.01 b	15.0 $\pm$ 3.5 cd	3.0 $\pm$ 1.2 c
abamectin	0.22 $\pm$ 0.08 b	0.08 $\pm$ 0.03 b	12.0 $\pm$ 4.6 cd	6.0 $\pm$ 1.9 bc
propargite	0.39 $\pm$ 0.17 b	0.09 $\pm$ 0.05 b	17.0 $\pm$ 5.8 cd	6.0 $\pm$ 2.5 bc
untreated	44.83 $\pm$ 13.22 a	21.94 $\pm$ 5.50 a	100 a	98.0 $\pm$ 2.0 a
P-value	<0.001	<0.001	<0.001	<0.001

¹Values followed by the same letter within a column and during the same time measurement period are not significantly different.

TABLE 3: Mean number of juvenile and adult CRM per fruit and mean percentage of fruit infested for each treatment in Trial 1. Values are the treatment mean $\pm$ SEM.

Treatment	Mean number of mites per fruit	Percentage of fruit infested with mites
Pre spray 2		
0.5% oil	6.12 $\pm$ 1.67 b ¹	76.0 $\pm$ 6.9 ab
1% oil	4.12 $\pm$ 2.14 b	54.7 $\pm$ 15.1 bc
milbemectin	0.89 $\pm$ 0.73 b	17.3 $\pm$ 9.6 cd
fenpyroximate	0.25 $\pm$ 0.02 b	13.3 $\pm$ 3.7 cd
abamectin	0.12 $\pm$ 0.07 b	5.3 $\pm$ 3.9 d
propargite	0.07 $\pm$ 0.07 b	5.3 $\pm$ 5.3 d
untreated	48.92 $\pm$ 13.85 a	100 a
P-value	<0.001	<0.001
3 weeks after spray 2		
0.5% oil	1.91 $\pm$ 1.21 b	33.3 $\pm$ 16.9 b
1% oil	0.88 $\pm$ 0.60 b	17.3 $\pm$ 6.9 bc
milbemectin	0 b	0c
fenpyroximate	0.09 $\pm$ 0.09 b	2.7 $\pm$ 2.7 bc
abamectin	0 b	0c
propargite	0.08 $\pm$ 0.05 b	6.7 $\pm$ 3.7 bc
untreated	61.81 $\pm$ 13.85 a	100 a
P-value	<0.001	<0.001
6 weeks after spray 2		
0.5% oil	1.00 $\pm$ 0.41 b	24.0 $\pm$ 2.7 b
1% oil	0.08 $\pm$ 0.04 b	6.7 $\pm$ 3.7 c
milbemectin	0.04 $\pm$ 0.03 b	4.0 $\pm$ 2.7 c
fenpyroximate	0.03 $\pm$ 0.03 b	2.7 $\pm$ 2.7 c
abamectin	0 b	0 c
propargite	0.03 $\pm$ 0.02 b	2.7 $\pm$ 1.6 c
untreated	46.28 $\pm$ 11.84 a	96.0 $\pm$ 2.7 a
P-value	<0.001	<0.001

¹Values followed by the same letter within a column and during the same time measurement period are not significantly different.

TABLE 4: Mean percentage of leaves and fruit infested with CRM eggs and juveniles plus adults in Trial 2. Values are the treatment mean $\pm$ SEM.

Treatment	Leaves		Fruit	
	Eggs	Juveniles +adults	Eggs	Juveniles +adults
Pre spray 1				
abamectin 25 ml	90.0 $\pm$ 4.5	90.0 $\pm$ 4.5	-	-
abamectin 37.5 ml	88.0 $\pm$ 9.7	92.0 $\pm$ 3.7	-	-
milbemectin	98.0 $\pm$ 2.0	98.0 $\pm$ 2.0	-	-
clofentezine	96.0 $\pm$ 4.0	96.0 $\pm$ 4.0	-	-
propargite	90.0 $\pm$ 7.7	96.0 $\pm$ 2.4	-	-
untreated	80.0 $\pm$ 11.0	86.0 $\pm$ 9.8	-	-
P-value	ns	ns	-	-
Pre spray 2				
abamectin 25 ml	62.0 $\pm$ 10.2	40.0 $\pm$ 5.5 ab ¹	36.0 $\pm$ 12.9 ab	10.0 $\pm$ 3.2 b
abamectin 37.5 ml	50.0 $\pm$ 14.1	30.0 $\pm$ 10.0 ab	20.0 $\pm$ 8.9 ab	2.0 $\pm$ 2 b
milbemectin	38.0 $\pm$ 11.6	66.0 $\pm$ 6.78 ab	12.0 $\pm$ 5.8 b	6.0 $\pm$ 2.4 b
clofentezine	70.0 $\pm$ 6.3	14.0 $\pm$ 7.5 b	32.0 $\pm$ 13.9 ab	6.0 $\pm$ 4 b
propargite	52.0 $\pm$ 11.1	20.0 $\pm$ 6.4 b	16.0 $\pm$ 9.8 b	42.0 $\pm$ 9.7 a
untreated	74.0 $\pm$ 13.6	76.0 $\pm$ 19.4 a	70.0 $\pm$ 6.3 a	86.0 $\pm$ 6.0 a
P-value	ns	0.001	0.019	<0.001
3 weeks after spray 2				
abamectin 25 ml	6.0 $\pm$ 4.0	0	0	0
abamectin 37.5 ml	6.0 $\pm$ 4.0	0	0	0
milbemectin	2.0 $\pm$ 2.0	0	0	0
clofentezine	0	0	0	0
propargite	0	0	0	0
untreated	0	0	0	0
P-value	ns	ns	ns	ns

¹Values followed by the same letter within a column and during the same time measurement period are not significantly different.

Trial 2 – CRM predators

The coccinellid ladybird *Stethorus* sp. and the stigmatid mite *Agistemus longisetus* were the most abundant predators in the trial (Table 5). Live *Stethorus* (viable eggs, larvae and adults) and evidence of *Stethorus* were present on leaves before the first spray application and there were no dead *Stethorus* found (Table 5). After the first spray application, the incidence of live *Stethorus* was lower in abamectin and clofentezine treated trees than in unsprayed trees. However, there were not significantly more dead *Stethorus* associated with this difference, indicating that the population had not been killed by the miticides but had dispersed from these trees due to a lack of food. Two applications of miticides significantly reduced the incidence and abundance of *A. longisetus* for all treatments when compared with control trees.

TABLE 5: Trial 2. Mean percentage of leaves infested with live and dead *Stethorus*, evidence of *Stethorus* and predatory mites before and after miticide treatments.

Treatment	Live <i>Stethorus</i>	Dead <i>Stethorus</i>	<i>Stethorus</i> evidence	Predatory mites
Pre spray 1:	($\Sigma^1 = 273$)	($\Sigma = 0$)	($\Sigma = 27$)	($\Sigma = 182^2$)
abamectin 25 ml	14 $\pm$ 6	0	2 $\pm$ 2	28 $\pm$ 15
abamectin 37.5 ml	18 $\pm$ 8	0	0	14 $\pm$ 10
milbemectin	12 $\pm$ 8	0	6 $\pm$ 4	18 $\pm$ 9
clofentezine	10 $\pm$ 3	0	0	20 $\pm$ 10
propargite	26 $\pm$ 8	0	2 $\pm$ 2	12 $\pm$ 6
untreated	18 $\pm$ 14	0	8 $\pm$ 5	4 $\pm$ 2
P-value	ns	ns	ns	ns
Pre spray 2:	($\Sigma = 162$)	($\Sigma = 60$)	($\Sigma = 390$)	($\Sigma = 114^3$)
abamectin 25 ml	4 $\pm$ 2 b	6 $\pm$ 2	12 $\pm$ 8	18 $\pm$ 11 ab
abamectin 37.5 ml	0 b	6 $\pm$ 4	14 $\pm$ 7	6 $\pm$ 4 ab
milbemectin	14 $\pm$ 5 ab	4 $\pm$ 4	20 $\pm$ 11	32 $\pm$ 13 a
clofentezine	6 $\pm$ 2 b	6 $\pm$ 6	20 $\pm$ 9	4 $\pm$ 2 ab
propargite	16 $\pm$ 7 ab	8 $\pm$ 4	12 $\pm$ 8	0 b
untreated	32 $\pm$ 4 a	0	28 $\pm$ 17	22 $\pm$ 7 ab
P-value	<0.01	ns	ns	0.03
3 weeks after spray 2	($\Sigma = 0$)	($\Sigma = 39$)	($\Sigma = 399$)	($\Sigma = 57^4$)
abamectin 25 ml	0	2 $\pm$ 2	8 $\pm$ 6	4 $\pm$ 2 b
abamectin 37.5 ml	0	8 $\pm$ 6	12 $\pm$ 6	0 b
milbemectin	0	4 $\pm$ 4	32 $\pm$ 15	6 $\pm$ 4 b
clofentezine	0	4 $\pm$ 2	26 $\pm$ 10	2 $\pm$ 2 b
propargite	0	0	16 $\pm$ 9	0 b
Unsprayed	0	2 $\pm$ 2	34 $\pm$ 9	38 $\pm$ 11 a
P-value	ns	ns	ns	<0.001

¹The total number found at each sampling time.

²97.6% of these were predatory mites *Agistemus longisetus* and 3.3% *Phytoseiulus persimilis*.

³99.1% of these were predatory mites *Agistemus longisetus* and 0.9% *Amblyseius largoensis*.

⁴100% of these were predatory mites *Agistemus longisetus*.

DISCUSSION

In the first trial, milbemectin, abamectin, fenpyroximate and propargite were consistently most effective against CRM eggs and other life stages. These four treatments consistently reduced the percentage of mite infestations and the mean number of mites on both fruit and leaves in comparison with unsprayed trees. The effects persisted until at least 6 weeks after the second spray application.

In the second trial the *Stethorus* sp. ladybird and *Agistemus longisetus* predatory mite activity masked the efficacy of the products tested. The ability of these predators to reduce CRM populations has previously been documented (Jamieson et al. 2005, 2008). However, a single application of abamectin, milbemectin, propargite and clofentezine was effective against CRM 2 weeks after application.

In a previous efficacy trial a single application of milbemectin was not effective at reducing the incidence of CRM eggs and had only an initial knock down effect on other life stages (Little & Harty 2004). In this trial it took a second spray application to significantly reduce the incidence of eggs. Abamectin is in the same chemical group as milbemectin but has been reported to have a broader spectrum of activity and is also effective against Kelly's citrus thrips (Jamieson et al. 2003; McKenna et al. 2004). Fenpyroximate is a phenoxy pyrazole and is therefore a different chemical grouping than the two avermectin products. Spider mites are well known for their capacity to develop resistance to many classes of insecticide and miticide (Chapman & Martin 2003). Resistance management strategies can minimise the chances of developing resistance and recommend not using more than two applications of miticides per season from the same chemical group.

The 1% mineral oil treatment reduced the population of CRM more effectively than the 0.5% treatment. The use of oil to control mites in an IPM programme is advantageous, as the chance of development of resistance is minimal. Although no phytotoxic damage was observed in any of the treatments and the use of mineral oil at a concentration of 1% is registered, growers should be mindful of any phytotoxic effects from using oils at higher rates.

In conclusion, there appears to be good potential for a range of products from different chemical groups to provide control of CRM.

ACKNOWLEDGEMENTS

We would like to thank Andrew Harty and Kerifresh for use of the trees at the trial site, Tim Machin, Ted Dawson and Peter Sutton for assistance with spray application, and Bob Fullerton and Fran Harris for assisting with assessments. This project was funded by MAF Sustainable Farming Fund and New Zealand Citrus Growers Inc.

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