EVALUATION OF TWO SEASONS OF ACARICIDE ROTATION TRIALS ON SPIDER MITE (ACARI: TETRANYCHIDAE) RESISTANCE IN SAN JOAQUIN VALLEY COTTON

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Abstract

With significantly higher spider mite densities in 1995 compared to 1994, the following results were observed - 1) *T. turkestani* was the dominant spider mite species during the early season before acaricides were applied, shifting to *T. urticae* thereafter; 2) *T. turkestani* continues to respond with almost complete susceptibility to dicofol (Kelthane®), propargite (Comite®) and abamectin (Zephyr®); and 3) *T. urticae* continues to exhibit high levels of resistance to Kelthane and Comite when exposed to these compounds. Residual leaf bioassays in the laboratory suggest that all rotations helped to reduce *T. urticae* resistance to Kelthane. Acaricide rotations were less effective in reducing resistance to Comite. The same field studies will be continued in the assigned plots in 1996 to further evaluate the effects of within-season rotations compared to single and multiple consecutive acaricide applications on spider mite resistance.

Introduction

In recent years, spider mites (*Tetranychus* spp.) have been elevated to the status of key pests of cotton alongside *lygus* bugs *(Lygus hesperus*) and aphids (*Aphis gossypii*) in the San Joaquin Valley (SJV), California. Strawberry mite (*Tetranychus turkestani* Ugarov and Nikolski), two-spotted mite (*T. urticae* Koch) and Pacific mite (*T. pacificus* McGregor) comprise the spider mite species causing economic damage to cotton (Leigh and Burton, 1976). The latter two spider mite species (*T. urticae* and *T. pacificus*) have developed resistance to two of the three acaricides currently used to control spider mites in California cotton, namely Kelthane (dicofol) and Comite (propargite) (Dennehy and Granett, 1984; Grafton-Cardwell et al., 1987; Bruce-Oliver and Grafton-Cardwell, 1995). *T. urticae* and *T. pacificus* will predictably develop resistance to the third and recently registered acaricide, Zephyr (abamectin), under routine and repeated patterns of use.

In 1994, we initiated long term field studies to test the concept of acaricide rotations within-season as a resistance-delaying or resistance-reducing strategy for spider mites on cotton. Some of the prerequisites for rotations to be successful in reversing resistance do exist in the SJV cotton cropping system, viz: the rotated acaricides have different chemistries and distinctly different modes of action, they have unstable resistance characteristics and have neutral or negative cross-resistance relationships (Georghiou et al., 1983). Abamectin (Zephyr®), the newly registered acaricide, which is being rotated with one of the older acaricides (Kelthane or Comite), belongs to a class of natural compounds (avermectins) with a novel mode of action. Produced from fermentation of the soil fungus *Streptomyces avermitilis* (Clark et al., 1994), Zephyr causes ataxia and paralysis in spider mites by stimulating the release of GABA (gamma-aminobutyric acid), an inhibitory neurotransmitter in arthropods (Fritz et al., 1979). Studies suggest that some arthropod strains resistant to organochlorines (e.g. Kelthane), organophosphates, carbamates or pyrethroids are not cross-resistant to Zephyr (Clark et al., 1994). More importantly, Dennehy et al. (1987) reported that dicofol resistance is unstable in spider mites found on SJV cotton. Similarly, Keena and Granett (1990) have suggested that propargite has unstable resistance.

We report herein the results of the second year of a 3 year acaricide resistance management program to determine if rotating dicofol (Kelthane), propargite (Comite) or abamectin (Zephyr) in commercial size cotton field plots can delay resistance to abamectin and reduce resistance to dicofol or propargite.

Materials and Methods

In replicated 4.3 acre field plots (150 rows 30 in wide by 500 ft long) at Corcoran, California, the following nine acaricide treatments were applied to test the effect of acaricide rotations on the evolution of resistance **- within-season rotations**: Treatment 2 - Kelthane (early)/Zephyr (mid season), Treatment 3 - Temik (at planting)+Kelthane (early)/Zephyr (mid season), Treatment 5 - Zephyr (early)/Comite (mid season), and Treatment 6 - kelthane (early)/Comite (mid season); **multiple consecutive acaricide applications**: Treatment 1 - Kelthane (early)/Kelthane (mid season) and Treatment 4 - Zephyr (early)/Zephyr (mid season); **single consecutive acaricide applications**: Treatment 7 - Comite (mid season), Treatment 8 - Zephyr (mid season), and Treatment 9 - Kelthane (mid season).

Each treatment was replicated four times in a randomized block experimental design. Blocking was against an irrigation gradient running from south to north. The early and the mid-season acaricide treatments were applied on 8 June and 13 July, 1995, respectively, using a Rogator 664 spray rig. As part of the data collection, we compiled spider mite density, species identification and resistance bioassay data following the same protocols as for the 1994 season and detailed in Bruce-Oliver and Grafton-Cardwell (1995). Residual whole leaf bioassays were performed with

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discriminating concentrations of 1000 ppm dicofol (Kelthane 4 MF, Rohm and Haas Co., Philadelphia, PA.), 1000 ppm propargite (Comite 30 WP, Uniroyal Chemical Co., Bethany, CT.), and 1 ppm abamectin (Agri-mek 0.15 EC, Merck and Co., AgVet Division, Rahway, N.J.), as well as a distilled water control (Table 2). To ensure a substantial spider mite infestation, acala cotton seeds were treated with an orthene seed treatment. Orthene (6 oz/acre) was also applied by air one and half weeks after seedling emergence to control an early infestation of thrips (*Frankliniella occidentalis*). A 0.57 acre section (rows 31-80) of each plot was harvested twice to obtain yield data. Mean seed cotton yields were compared using the Students-Neuman-Keuls multiple range test, $P < 0.05$ (SAS Institute, 1985).

Results and Discussion

Population dynamics:
Compared to the 1994 season, spider mite densities were much higher during 1995, ranging from zero mites/leaf one week after emergence of cotton seedlings to 8.0 all mite stages per leaf before defoliation. This increase in spider mites was due in part to both the orthene seed treatment and the orthene application by air a week after seedling emergence to control an early thrips infestation. However, the mean number of all mite stages per leaf in any treatment never exceeded the economic threshold level of 7-10 adult mites per leaf.

The highest pretreatment mean number of mites per leaf (1.7) for plots with treatments 1-6 was observed for treatment 6. Varying levels of control were achieved with the early and mid season acaricide treatments applied to these plots (Fig. 1). The early season Kelthane (3 pts/acre) and Zephyr (4 oz/acre) treatments successfully reduced spider mite populations to undetectable levels. However, the mid season Kelthane (3 pts/acre) and Comite (2 pts/acre) treatments applied to plots 1 and 6, respectively, did not reduce spider mite densities compared to the mid season Zephyr (8 oz/acre) treatments (plots 2, 3 and 4). The post-treatment mean number of all mite stages per leaf two weeks after application was 3.4 for plot 1 (Kelthane mid-season treatment) and 4.8 for plot 6 (Comite mid-season treatment) (Fig. 1).

Spider mite densities for plots with treatments 7-9 that did not receive an early season treatment, averaged 2.6mean mites/leaf (all stages) throughout the entire season. Because these plots were treated only at mid-season, the spider population had time to significantly increase to densities as high as 6.6 mites/leaf (treatment 7), much higher than for treatments 1-6 (Figs. 1 & 2). Initially, the mid-season single acaricide applications (Zephyr® 0.15EC, 8 oz/acre, Comite® 6E, 2 pts/acre, and Kelthane® MF, 3 pts/acre) sufficiently controlled the mite populations in plots 7-9, but the spider mite populations quickly rebounded in the plots that received Kelthane (plot 9) and Comite (plot 7) treatments. In the plots that received the single mid-season Kelthane (plot 9), spider mites (all stages) subsequently reached a mean of 8.0 mites/leaf (Fig. 2).

The species composition for all treatments was 51.2% *T. turkestani*, 48.8% *T. urticae*, and 0.03% *T. pacificus*. The pretreatment samples were predominantly *T. turkestani* (97.9%) compared to 2.1% *T. urticae*. All mites in the post-treatment samples were *T. urticae*, except for a single *T. pacificus* female. *T. turkestani*, which is fully susceptible to all three acaricides, was controlled by the treatments resulting in a complete shift in spider mite species to the acaricide resistant *T. urticae* and *T. pacificus* (Fig. 3 & 4). The species shift to the acaricide-resistant *T. urticae* explains the lack of efficacy of treatments 1 and 6 (Kelthane and Comite) at mid-season (Fig. 1 & 3). Similarly, the rebound observed in treatments 7 and 9 can be attributed to the inability of Kelthane and Comite to successfully keep *T. urticae* below detectable levels at mid-season (Fig. 2 & 4). *T. urticae* in SJV cotton has shown significant levels of resistance to both Kelthane and Comite (Dennehy and Granett, 1984; Grafton-Cardwell et al., 1987; Bruce-Oliver and Grafton-Cardwell, 1995). However, despite the inability of Kelthane and Comite to adequately reduce *T. urticae* densities at mid-season, seed cotton yields were not significantly different for the 9 treatments (SNK test, $P < 0.05$) (Table 1). Yields averaged 4895.1 lbs/0.57acre for the 9 treatments with treatment 4 (Zephyr/Zephyr) registering a high of 5037 lbs/0.57acre (Table 1). The absence of statiscal differences in seed cotton yields could be due to spider mite populations being continously maintained below the economic threshold of 7-10 adult mites/leaf.

Resistant frequencies:
T. turkestani was only found during pretreatment collection dates and exhibited nearly complete susceptibility to discriminating concentrations of Kelthane, Comite and Zephyr, with percentage mortality ranging from 93.8 to 100% (Table 2). *T. urticae* populations similarly responded with susceptibility to discriminating concentrations of Zephyr (81.2 - 100% mortality). The response of *T. urticae* to Kelthane and Comite varied depending upon treatment scheme (Table 2). Rotations resulted in higher average mortality than non-rotation strategies but the difference in mortality was greater for Kelthane than Comite.

T. urticae response to Kelthane - comparisons of the effects of rotations (treatments 2, 5 & 6) versus multiple consecutive (1 & 4) or single consecutive (7, 8, 9) acaricide treatments on the response of *T. urticae* populations to Kelthane shows that 1) with multiple consecutive uses of Kelthane, resistance to Kelthane evolved to higher levels and persisted well below the 80% mortality threshold, 2) rotations reduced resistance by shifting Kelthane resistance frequencies back towards susceptibility on some collection dates throughout the season, and 3) high levels of *T. urticae* resistance to Kelthane were observed but less so than for the multiple consecutive use of Kelthane, suggesting that single consecutive applications of Kelthane also resulted in field selection for Kelthane resistance. All the acaricide rotations, especially Kelthane/Comite, reduced Kelthane resistance for 5-6 weeks.

T. urticae response to propargite - The response of *T. urticae* to Comite was more difficult to discern because despite the varied responses, there were no significant differences between rotations versus non-rotations treatments on Comite resistance. The single consecutive Comite treatment produced both a decrease and an increase in Comite resistance. Acaricide rotations periodically reduced Comite resistance in *T. urticae* but not in any consistent manner, while fluctuations from susceptibility to resistance characterized the response of *T. urticae* to multiple consecutive Kelthane treatments.

With rotation treatments, we expect resistance to one acaricide to periodically decline while the other rotated acaricide is being used because of the relaxation of acaricide selection pressure. Conversely, with single and multiple consecutive acaricide treatments, we expect resistance to increase proportionally to the frequency of acaricide use. These expected trends are beginning to emerge in *T. urticae* for the 1995 season, but more so for Kelthane than Comite.

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Table 1. Yields (lbs of seed cotton/0.57acre) from 50 rows x 500 ft (rows 31-80) of 9 replicated acaricide treatment plots at Corcoran, California.

Scheme	Treatment	Mean Yield
Consecutive use	4.Zephyr(early)/Zephyr(mid)	5037.0a
Single use	9.Kelthane (mid season)	5024.0a
Rotation	3.Temik+Kelthane(early)/Zephyr(mid)	5014.5a
Rotation	5.Zephyr(early)/Comite (mid)	4990.0a
Rotation	2.Kelthane(early)/Zephyr (mid)	4921.5a
Single use	8.Zephyr (mid Season)	4814.0a
Rotation	6.Kelthane (early)/Comite (mid)	4785.0a
Single use	7.Comite (mid)	4752.0a
Consecutive use	1.Kelthane (early)/Kelthane (mid)	4718.0a

Means followed by the same letter are not significantly different at $P<0.05$ (Students-Neuman-Keuls multiple range test).

Table 2. Range and mean percentage mortality of *T. turkestani* and *T. urticae* to residual whole leaf bioassays of the acaricides dicofol, propargite, and abamectin.

Acaridcide (Discriminating Concentration)	%Mortality of *T. turkestani* rotations	nonrotations
Abamectin (1 ppm Agri-mek.15EC)	93.8-100% $\bar{x}$ =97.9% N=3	100% N=5
Dicofol (1000 ppm Kelthane 4MF)	100% N=3	100% N=5
Propargite 1000 ppm Comite 30WS	98.7-100% $\bar{x}$=99.6 N=3	97.8-100% $\bar{x}$=99.3% N=5
Acaridcide (Discriminating Concentration)	**%Mortality of *T. urticae* rotations**	**nonrotations**
Abamectin (1 ppm Agri-mek.15EC)	95.8-100% $\bar{x}$=99.4% N=15	81.2-100% $\bar{x}$=98.2% N=22
Dicofol (1000 ppm Kelthane 4MF)	23.9-100% $\bar{x}$=70.4% N=16	12.7-100% $\bar{x}$=57.1% N=22
Propargite 1000 ppm Comite 30WS	40.8-90.3% $\bar{x}$=69.3% N=15	23.4-97.2% $\bar{x}$=61.8% N=22

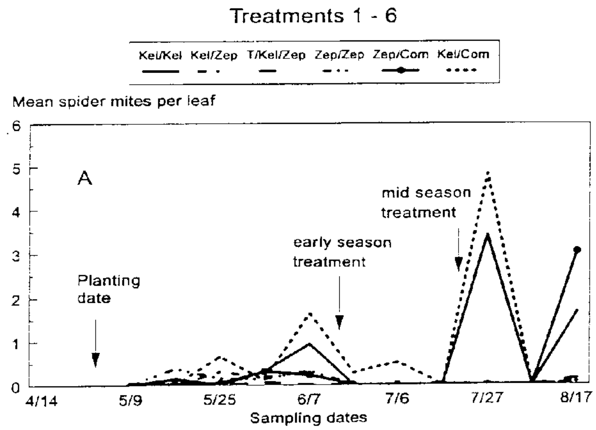

Figure 1. Spider mite densities for treatments 1-6 during 1995 season at Corcoran, CA.

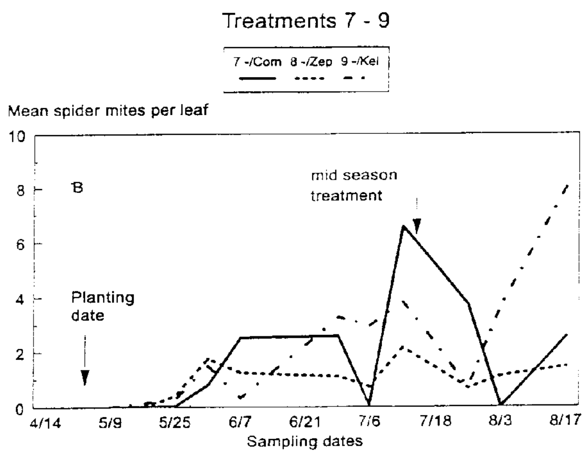

Figure 2. Spider mite densities for treatments 7-9 during 1995 season at Corcoran, CA.

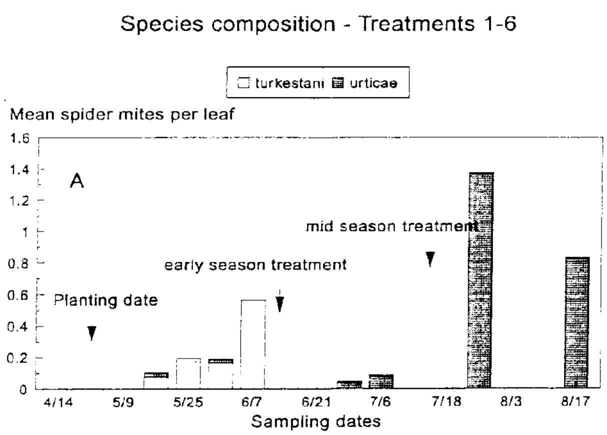

Figure 3. The species composition of spider mites averaged for treatments 1-6 during the 1995 season at Corcoran, CA.

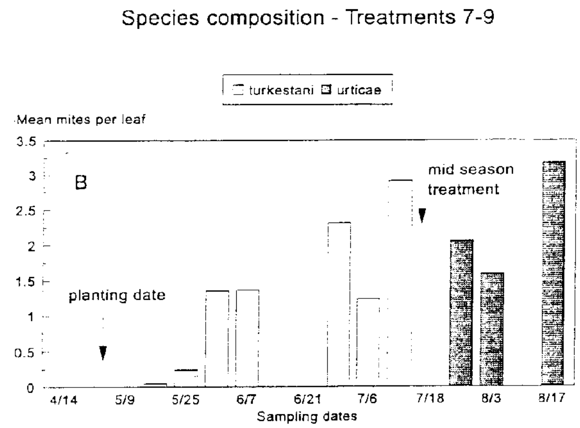

Figure 4. The species composition of spider mites averaged for treatments 7-9 during the 1995 season at Corcoran, CA.