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Natural Enemies Survey in Ventura County Avocado Groves in 2003 and 2004

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Project history

These studies are also known as (a part of) BIOSA, a project aiming to develop a "Biologically Intensive Orchard System for Avocado" which would ultimately integrate non-chemical pest control methods and cultural management into a suggested method for growing avocado with fewer pesticides. Pruning, mulching, planting several plant species on the orchard floors, different means of fertilization and release of potential natural enemy (NE) agents for biological control were planned for subsequent years after establishing the current practices for managing avocado thrips problems and identifying the species and numbers that make up the resident natural enemy populations in avocado groves. Time restrictions and limitations of manpower have resulted in this 2-year survey of avocado thrips and their potential natural enemies in 2003 and 2004, with correlations of natural enemies with distance from the coastline and fraction of orchard floor covered with leaf duff, living or flowering plants. No continuation of the BIOSA project is currently planned.

Introduction

Avocado thrips (*Scirtothrips perseae* Nakahara) has been a major pest in California avocado groves since it was first found in Ventura County in 1996 (Hoddle and Morse, 1997). Most growers are currently using chemical means to control their invertebrate pest problems and research into these areas is ongoing (Yee *et al*., 2001ab; Oevering *et al*. 2002; Morse and Hoddle, 2003). Foreign exploration studies for natural enemies identified six genera of predatory thrips (*Aeolothrips*, *Aleurodothrips*, *Franklinothrips*, *Leptothrips*, *Scolothrips* and *Karnyothrips*), one parasitoid (*Ceranisus*) and one predatory mite (*Balaustium*) associated with avocado thrips in Mexico and Guatamala (Hoddle *et al*., 2002). In Ventura county, *Franklinothrips orizabensis* (Johansen) and *Aeolothrips kuwanaii* (Moulton) were reported associated with higher numbers of avocado thrips in a three year study from 1998-2000 (Yee *et al*., 2001c). Since 2000, possible biological control measures against avocado thrips have been investigated, including releases of California

native generalist predators *F. orizabensis* (Oevering *et al*., 2002, Hoddle *et al*., submitted) and C*hysoperla* sp. (Phillips and Faber, 1999). So far none of these studies have developed into a commercially available strategy, although some organic growers have adopted a practice of releasing generalist predators with varying results (Oevering, personal observations).

Since reliance on biological control remains the preferred method of pest control for most avocado growers, the focus for this study returned to natural enemies already present in the California groves. In Ventura County, during the *F. orizabensis* release studies, a variety of generalist natural enemies were found on the sticky cards used to monitor *F. orizabensis* in the groves (Oevering, personal observation). To identify generalist predators and parasitoids that may affect the thrips populations and their spatial and temporal distribution, a survey for natural enemies in chemically treated and untreated groves in Ventura County was piloted on 3 sites in 2002 and expanded to include 14 sites in 2003 and 2004. This paper presents the results of the natural enemies survey and the avocado thrips problem in treated and untreated groves in Ventura County, together with their location in relationship to the coast and their relationship with organic cover of the orchard floor. It was assumed that this information would shed light on the natural situation in untreated groves, which have not been studied intensively in the past.

Materials and Methods

Observation groves

In 2003, 14 avocado groves were selected, located between 1.6 and 24.4 miles from the coast. Groves were at least 90% 'Hass' avocado, 7-15 feet tall and 5 to 15 years of age (older groves were avoided because they were often heavily pruned or stumped in the recent past). 5 groves in 2003 and 6 groves in 2004 were treated once with abamectin and 2% NR oil for avocado thrips control. One untreated grove in 2003 was treated in 2004 and one treated grove in 2003 remained untreated in 2004. In 2004, an untreated grove 12.18 miles from the coast was replaced by one 6.8 miles from the coast. In each grove10 trees (2 sites of 5 trees at least 10 rows apart) were observed every two weeks from January 2003 through August 2004.

Observations

During the time of each observation, a phenological score was given to each of the five observation trees per site. For each tree quadrant, 5 branch tips were randomly chosen and awarded a point when in flush and no points when the branch tip had mature leaves. This rendered a tree score between 0 and 20, where 0 is a tree without flush and 20 a tree in full flush.

In October 2003 and 2004 an estimate of fruit damage and yield was obtained for each grove by counting the number of fruit on each tree for the 10 observation trees per grove. Fruit damage was estimated by determining the percentage fruit surface scarred by avocado thrips for each individual fruit.

Immature and adult avocado thrips (AT) and generalist natural enemy species (NE) (listed in Table 1) present on 10 flushing leaves per tree were counted during each observation. Four branches of each tree (one per quadrant) were each hit three times onto a blue tray (12x16 inches) and any NE present on the tray were recorded. Six yellow sticky cards (6x6 inch) were hung underneath the canopy (3 in each set of 5 trees). The cards were

changed with every field observation. NE trapped on the sticky cards were identified and counted in the laboratory.

Table 1. *Name and abbreviations used for arthropod species recorded in leaf counts, beat samples or sticky cards in 2003 and 2004.*

	Arthropod species	Common name	Abbreviation
	Predatory HEXAPODA		
Predatory thrips (Thysanoptera)	*Franklinothrips orizabensis*	NA	FT
	Leptothrips mali	Black hunter	BH
	Aeolothrips fasciatus	Banded thrips	BT
	Scolothrips sexmaculatus	Six spotted thrips	6SP
	Leptothrips mcconnelli	NA	LM
Predatory beetles (Coleoptera)*	*Stethorus picipes*	Spider mite distroyer	ST
	Coccinellidae	Lady beetles	LB
	Staphylinidae	Rove Beetles	RB
Lacewings (Neuroptera)*	Chrysopa spp.	Green lacewings	LW
True Bugs (Hemiptera)*	*Orius* & Anthocoris sp.	Minute pirate bugs	PB
Parasitoids: Eulophidae (Hymenoptera)	*Ceranisus menes*	NA	CM
	Predatory ARACHNIDAE		
Predatory mites (Acari)*	Anystidae sp.	Whirley gigs	WG
Spiders (Araneae)*	Jumping, Crab and Orchard spiders		SP
	Herbivore HEXAPODA		
Avocado thrips	*Scirtothrips perseae*	Immatures	L12
		Adults	AT

NA no common name
* not identified to species level in these studies

NE data used in analyses

The species and number of NE trapped on sticky cards and found in beat samples vary as the observation methods are not equally effective for all species. The leaf counts provided insufficient data on arachnid NE and insect NE. Fewer than 100 specimens of six spotted thrips, big eyed bugs, syrphid flies, and parasitoids other than *Ceranises menes* were recorded per year in either beat samples or sticky card samples, and were therefore not included in the analyses. The sticky cards yielded sufficient data for the remaining insect NE, but not for arachnid NE. The sticky card data indicate the number of insects flying through the orchard and the observed numbers are taken as an indication of abundance. Beat samples yielded sufficient data on arachnid NE, but not for insect NE. Data on predatory mite species other than Anystidae was not collected from all sites and therefore omitted from analyses.

Analyses

Most data obtained in these studies are descriptive and cannot be used in statistical analyses. Where possible the data was analyzed using ANOVA, $P<0.05$. Correlations between abundance and distance from the coast were examined for species in untreated groves using best of fit tests on all models. The models are listed only when significant relationships (ANOVA, $P<0.05$) were found.

Results and Discussion

Harvest

The number of fruit set per tree in 2003 exceeded the fruit set in 2004, but for both years the number of fruit set in untreated groves did not differ significantly from the conventionally treated groves (ANOVA, P>0.05). The number of fruit with more than 10% surface scarring was not significantly different in untreated and conventionally treated groves either (ANOVA, P>0.05) (Table 2). This indicates that the AT populations were sufficiently suppressed by the treatments to prevent excessive scarring or that the AT populations at untreated sites did not exceed the economical thresholds.

In the 6 conventionally treated groves the numbers of AT per leaf exceeded the economical threshold levels (3-5 immature AT per leaf) during April, May and June in both 2003 and 2004. Following treatment the numbers were suppressed below 3 per leaf at all sites in July (Figure 1A).

In the 11 untreated groves the number of AT exceeded 3 per leaf in May, June and July 2003 and dropped below that level in early August, 2003.

Table 2. *Mean number of fruit set per tree in 2003 and 2004 ± SE and percentage of fruit with >10% fruit surface scarring ± SE observed per tree at 4 conventionally treated and 10 untreated avocado groves in Ventura County, CA.*

	No control (N=10)	Conventional control (N=4)	ANOVA	
Mean fruit set on trees			F	*P*
2003	293.7 ± 38.09	353.5 ± 106.36	0.46	0.5103
2004	141.9 ± 22.71	193.8 ± 3.64	1.98	0.1849
2003 + 2004	435.6 ± 49.16	547.3 ± 108.38	1.19	0.2963
Percentage fruit with >10% surface scarred				
2003	6.41 ± 1.91	3.97 ± 2.84	0.48	0.5014
2004	5.29 ± 3.80	0.00 ±0.00	0.74	0.4076
2003 + 2004	5.45 ± 1.99	2.73 ± 2.14	0.62	0.4473

In 2004, the AT numbers were high throughout the season in a grove 16.25 miles from the coast. In two other groves the immature AT numbers exceeded 3 per leaf in June, July or August 2004, while at other locations the numbers remained below 3 per leaf throughout the summer (Figure 1B). The lack of fruit scarring and the relatively low number and delayed population development of AT in untreated groves, suggests that natural enemies may be involved.

Theoretically, the observed low thrips scarring in the untreated groves may be related to a lesser quality or quantity of food (flushing avocado leaves) available to the avocado thrips, delaying the AT development. However, the phenological scores of the trees in conventionally treated groves and untreated groves did not indicate any significant difference in the amount of flushing leaves available between April and July 2003 and 2004 (Figure 2A, B).

Natural Enemies 1: Predatory Thrips

Franklinothrips orizabensis (FT), the predatory thrips species first selected as a potential NE for commercial use (Hoddle et al., 2004) was the second most abundant predatory thrips species after *Leptothrips mali* (black hunter) (BH) on sticky cards in 2003 and it was the most abundant predatory thrips species in 2004 (Table 3).

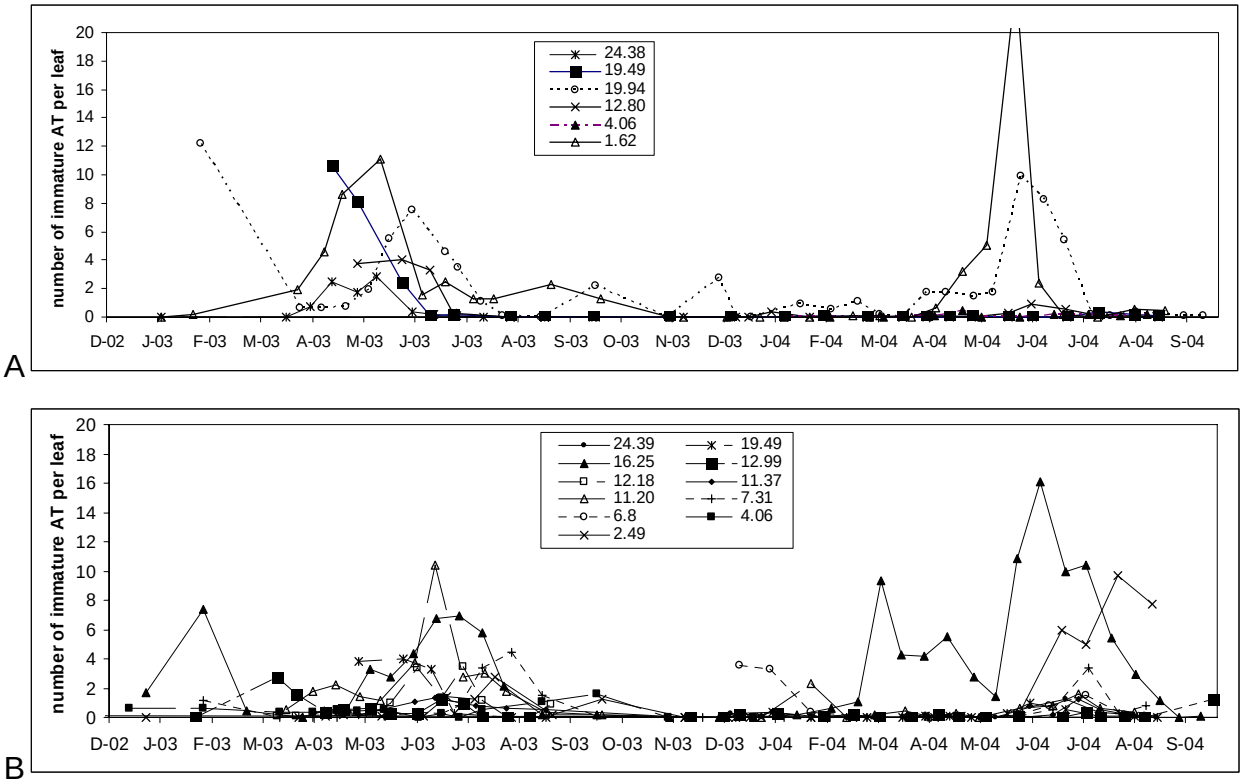
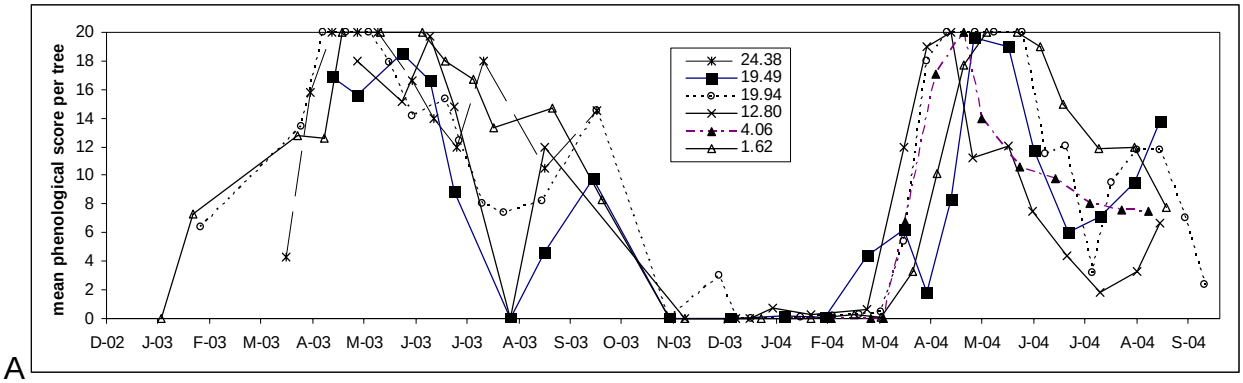


Figure 1. *Mean number of immature AT per leaf observed on ten trees per avocado grove in Ventura County in 2003 and 2004 (A conventionally treated groves; B untreated groves; locations by distance in miles from the coast).*

Table 3. *Total number of Natural Enemies recorded in beat samples and on sticky cards in 2003 and 2004.*

	Beat samples		Sticky cards	
	2003	*2004*	*2003*	*2004*
FT	69	85	2684	4535
BH	280	67	6011	3846
BT	14	9	221	263
LM	25	4	739	318
PB	58	2	680	355
CM	41	6	2631	1442
ST	269	57	2493	4994
LB	268	128	3888	339
LW	187	42	511	288
WG	295	233	4	2
SP	387	254	65	485

FT were abundant throughout the year, and no major difference was found between treated and untreated groves (Figure 3 AB). In 2003, there was no significant correlation of FT with distance from the coast (F=1.11, *P*=0.3079) and no fit (apparent correlation) was found for 2004. BH numbers were affected by treatments, with populations disappearing from treated groves in July 2003 and 2004 (Figure 4A). In untreated at coastal intermediate and inland groves the BH numbers remained high throughout the summer in 2003 but dwindled after June in 2004 (Figure 4B). No fit was found correlating the BH numbers to distance from the coast in 2003. In 2004, there was no significant correlation of BH with distance from the coast (F=2.43; *P*=0.1387).



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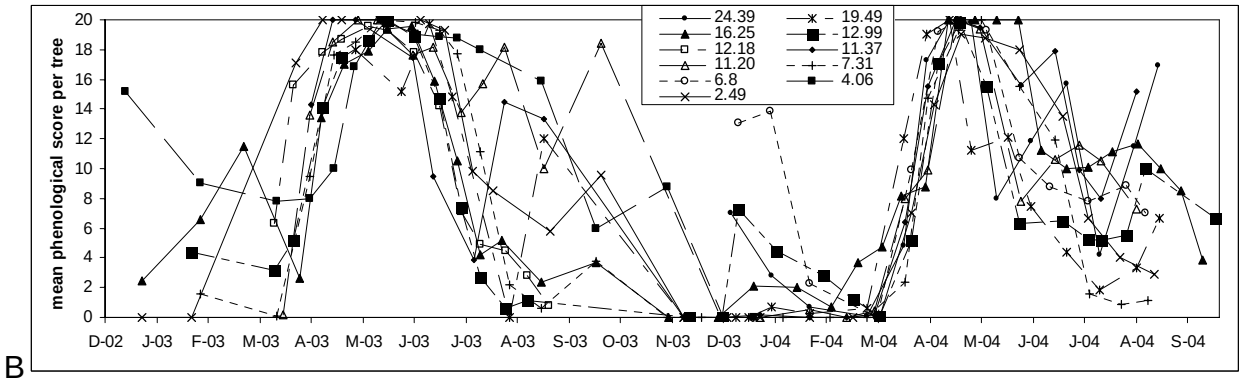

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Figure 2. *Mean phenological score of ten trees per avocado grove in Ventura County in 2003 and 2004 (A conventionally treated groves; B untreated groves; locations by distance from the coast; 0 indicates a tree with all mature leaves; 20 indicates a tree with all flushing leaves).*

FT are likely to aid in the suppression of AT numbers in spring, but also seem to use food sources other than AT to sustain their population as was observed in treated groves with few or no AT prey. The data imply a larger role for BH in suppressing AT numbers which show AT starting to increase soon after the BH numbers dwindle. The presence of flowers and Western Flower Thrips (WFT), from April through June, in avocado orchards may imply that BH feeds primarily on WFT and secondarily on AT. If AT was the main food source for BH, the disappearance of BH when AT is still available would have been unlikely.

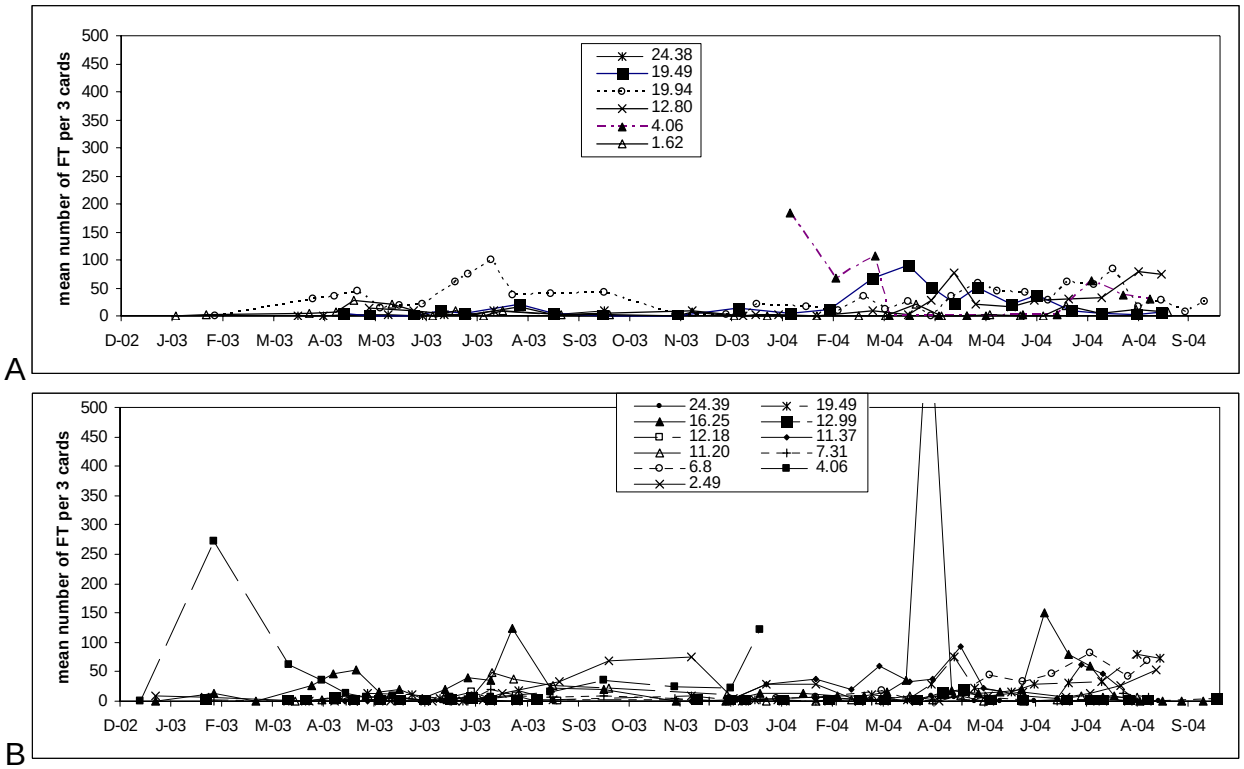

Figure 3. *Mean number of* Franklinothrips orizabensis *trapped per 3 sticky cards per avocado grove in Ventura County in 2003 and 2004 (A conventionally treated groves; B untreated groves; locations by distance in miles from the coast).*

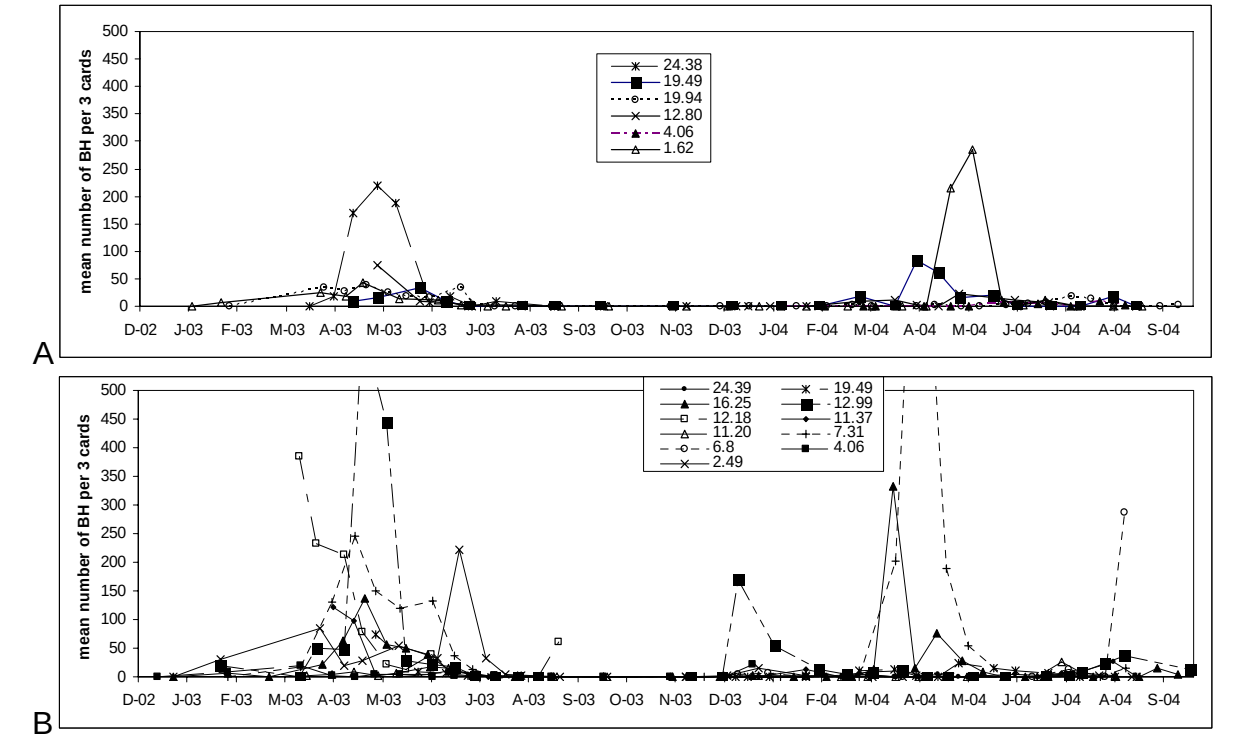

Figure 4*. Mean number of* Leptothrips mali *(Black Hunters) trapped per 3 sticky cards per avocado grove in Ventura County in 2003 and 2004 (A conventionally treated groves; B untreated groves; locations by distance in miles from the coast).*

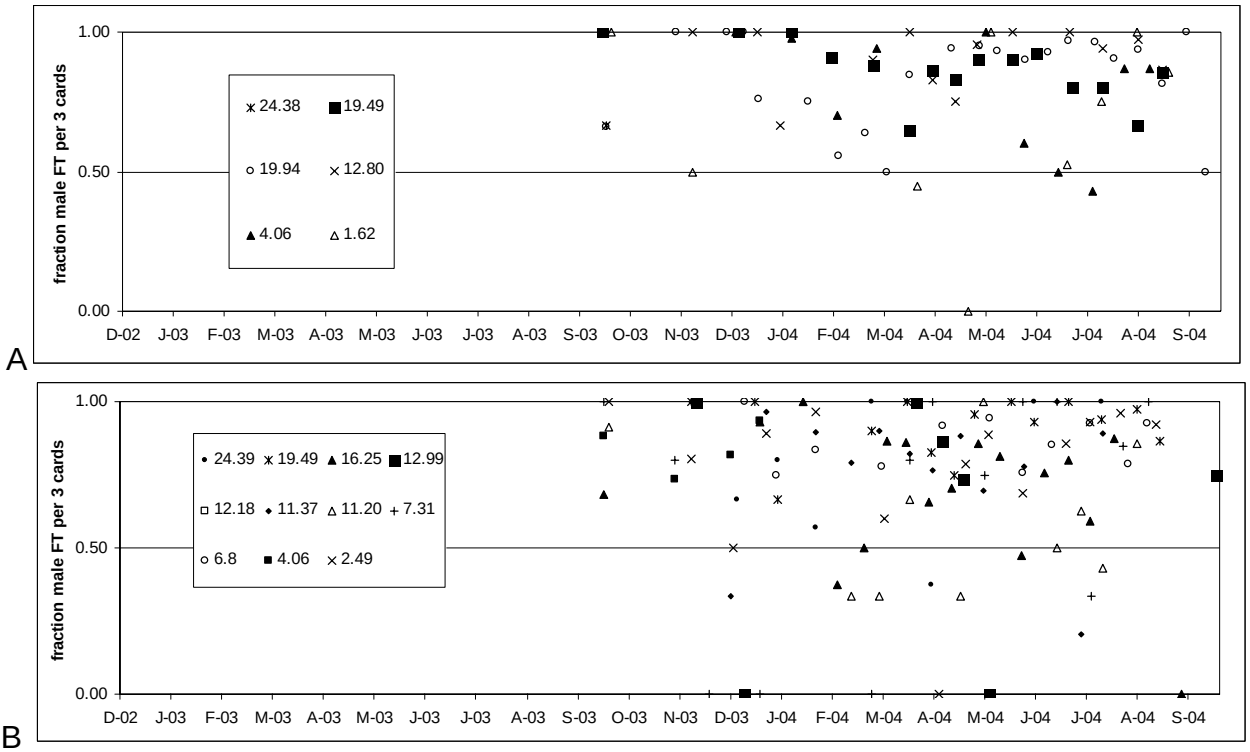

Figure 5. *Fraction of male* Franklinothrips orisabensis *trapped per 3 sticky cards per avocado grove in Ventura County in 2004 (A conventionally treated groves; B untreated groves; locations by distance in miles from the coast, 1 indicates all males, 0 indicates all females).*

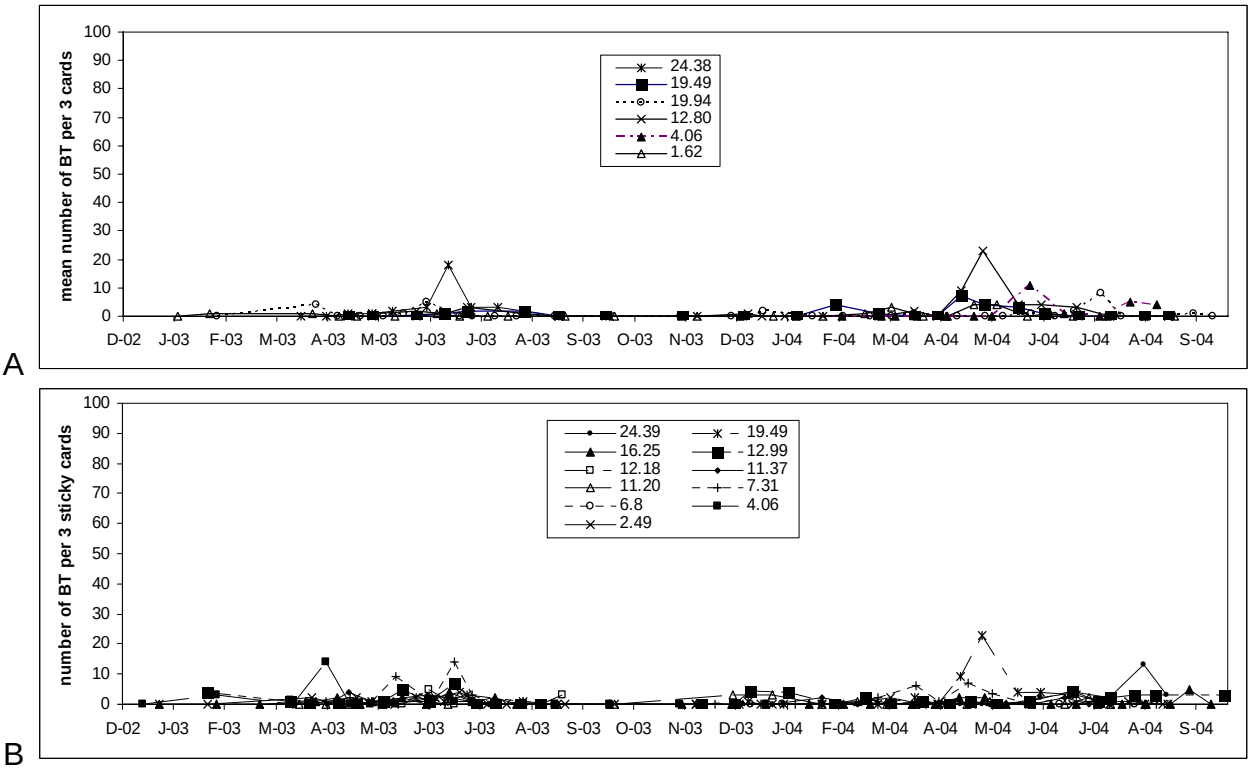

Figure 6*. Mean number of* Aeolothrips fasciatus *(Banded thrips) trapped per 3 sticky cards per avocado grove in Ventura County in 2003 and 2004 (A conventionally treated groves; B untreated groves; locations by distance in miles from the coast).*

The FT population did not fluctuate much and seemed to slowly decrease with time. This lack of population growth may be related to food availability or to a male bias in the population. The sex ratio of FT populations in captivity has been largely male biased and underlies one of the problems of FT mass production. However, this survey also found a male bias in the groves, with no difference between the treated (mean male ratio ± SD = 0.83±0.193) and untreated groves (mean male ratio ± SD = 0.74±0.277) (Figure 5 AB).

Of the other two predatory thrips species in Ventura County, low numbers of *Aeolothrips fasciatus* (banded thrips) (BT) are present in both treated and untreated avocado groves (Figure 6AB). In 2003, no fit was found for correlation of BT with distance from the coast; in 2004 none of the apparent correlations was significant (F=1.92, *P*=0.1852). The low numbers of BT are unlikely to impact AT populations.

Leptothrips mcconelli (LM) was more abundant in untreated than in treated avocado orchards, but their numbers were also low compared with FT or BH (figure 7AB). In 2003, none of the apparent correlations of LM with distance from the cost was significant (F=0.76, *P*=0.3949); no fit was found for 2004.

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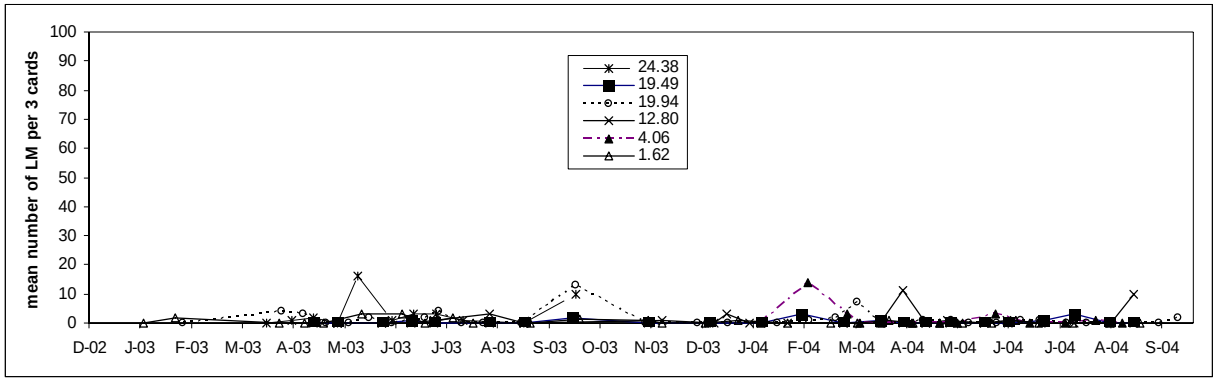

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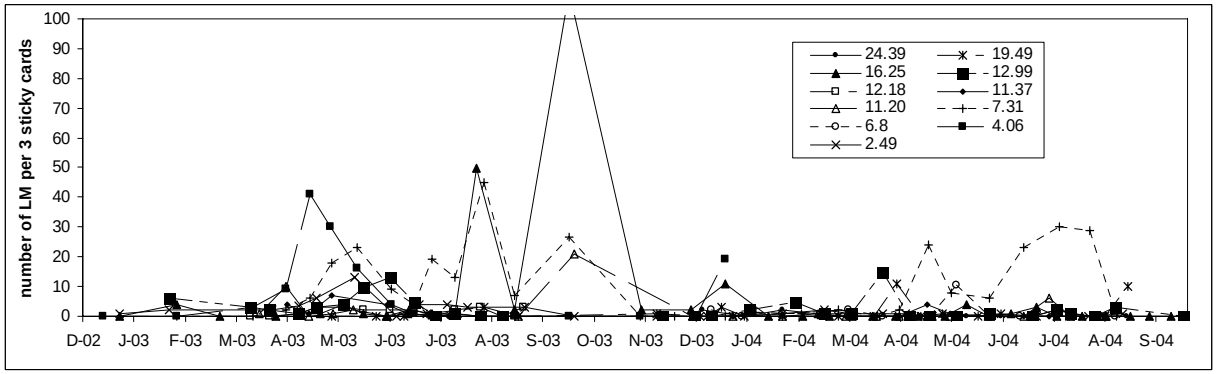

Figure 7. *Mean number of* Leptothrips mcconnelli *trapped per 3 sticky cards per avocado grove in Ventura County in 2003 and 2004 (A conventionally treated groves; B untreated groves; locations by distance in miles from the coast).*

The data on predatory thrips species in this survey indicate that none of the four species (FT, BH, BT and LM) are ideal candidates for commercial use to suppress AT numbers. In untreated groves however, each species is likely to contribute to the delayed population development of AT and aid in the natural suppression of AT numbers.

Natural Enemies 2; *Minute pirate bugs and* Ceranisus menes

Minute pirate bugs (PB) are used as effective but expensive biological control agents against thrips in protected cultivation. In the Ventura avocado orchards, low levels were present in the natural NE population of treated and untreated groves between March and September in 2003 and between March and July in 2004 (Figure 8AB). The presence of PB in avocado groves may play a role in the suppression of AT, but PB may also take immature predatory thrips species as prey. In 2003, the correlation presented in a linear relationship was significant (F=8.74, *P*=0.0093: PB=-0.322 + 0.208 *distance from the coast in miles; R^2=35.33, correlation coefficient = 0.5944). This means that PB numbers are higher at shorter distances from the coast. No fit was found for 2004.

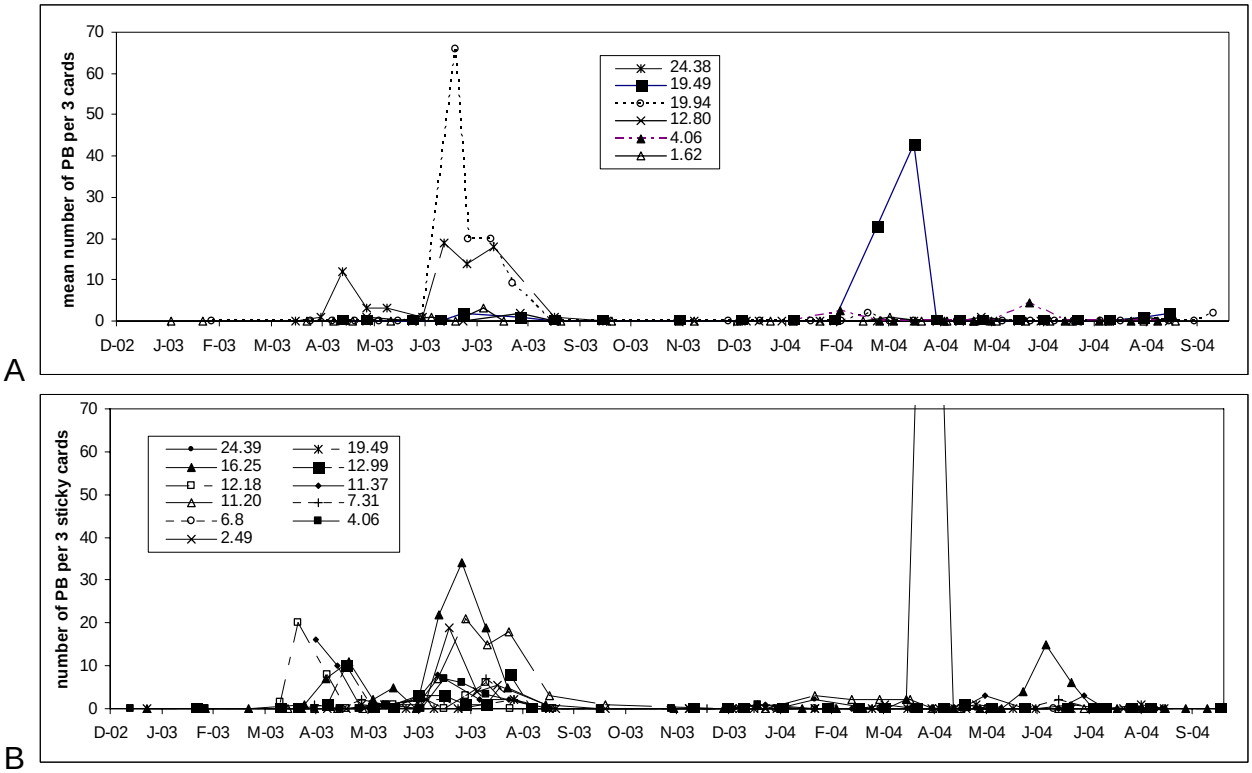

Figure 8. *Mean number of minute pirate bugs (*Orius *and* Anthocoris *species) trapped per 3 sticky cards per avocado grove in Ventura County in 2003 and 2004 (A conventionally treated groves; B untreated groves; locations by distance in miles from the coast).*

Another thrips specialist that may affect both the AT and the predatory thrips population is the generalist thrips parasitoid *Ceranisus menes* (CM). CM has been observed to parasitize first instar AT in the groves, but in the literature this species has been reported to be marginally effective for biological control, parasitizing up to 28% of a thrips population (Castineiras *et al* 1996). After the first observations of CM in Ventura County in 2002, it was included in this survey and regularly observed in untreated groves throughout both years (Figure 9AB). In 2003, no fit was found for correlation between CM numbers and distance from the coast. In 2004, the correlation presented in a reciprocal relationship was significant (F=60.44, *P*<0.0001: CM=-4.799 + 73.79/distance from the coast in miles; R^2=79.01, correlation coefficient = 0.8892). This means that CM numbers are higher at shorter distances from the coast.

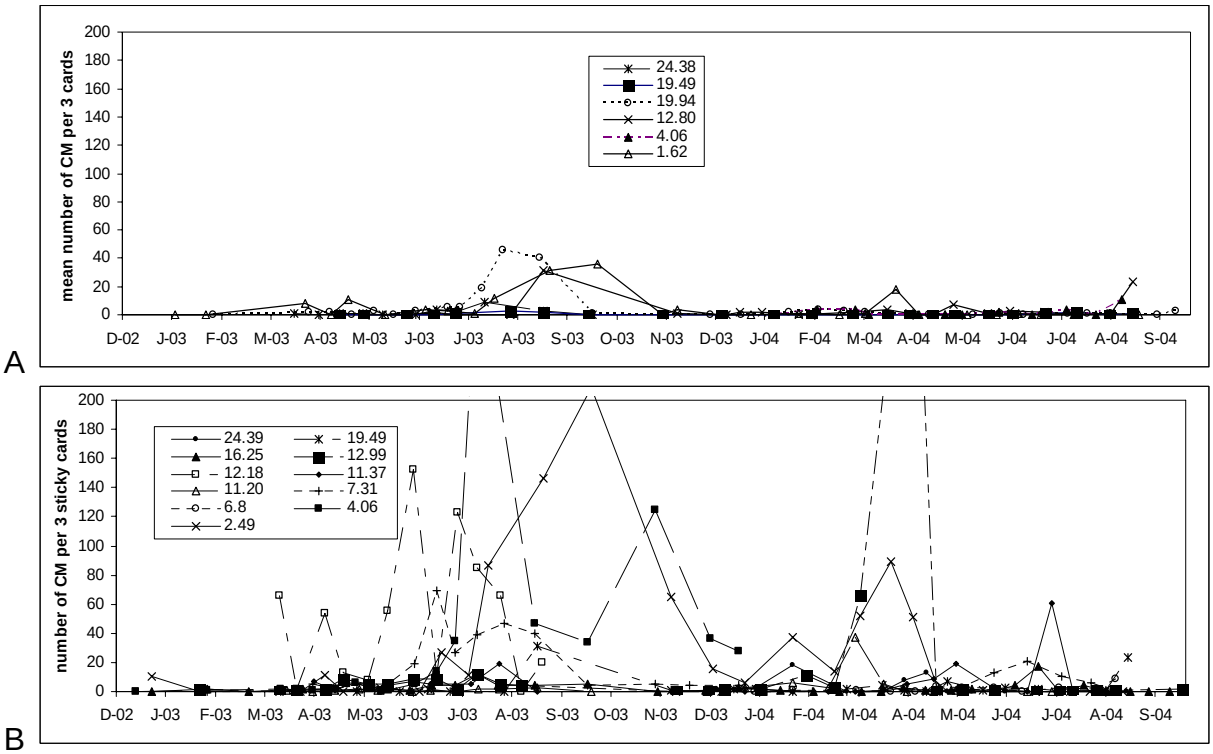

Figure 9. *Mean number of* Ceranisus menes *trapped per 3 sticky cards per avocado grove in Ventura County in 2003 and 2004 (A conventionally treated groves; B untreated groves; locations by distance in miles from the coast).*

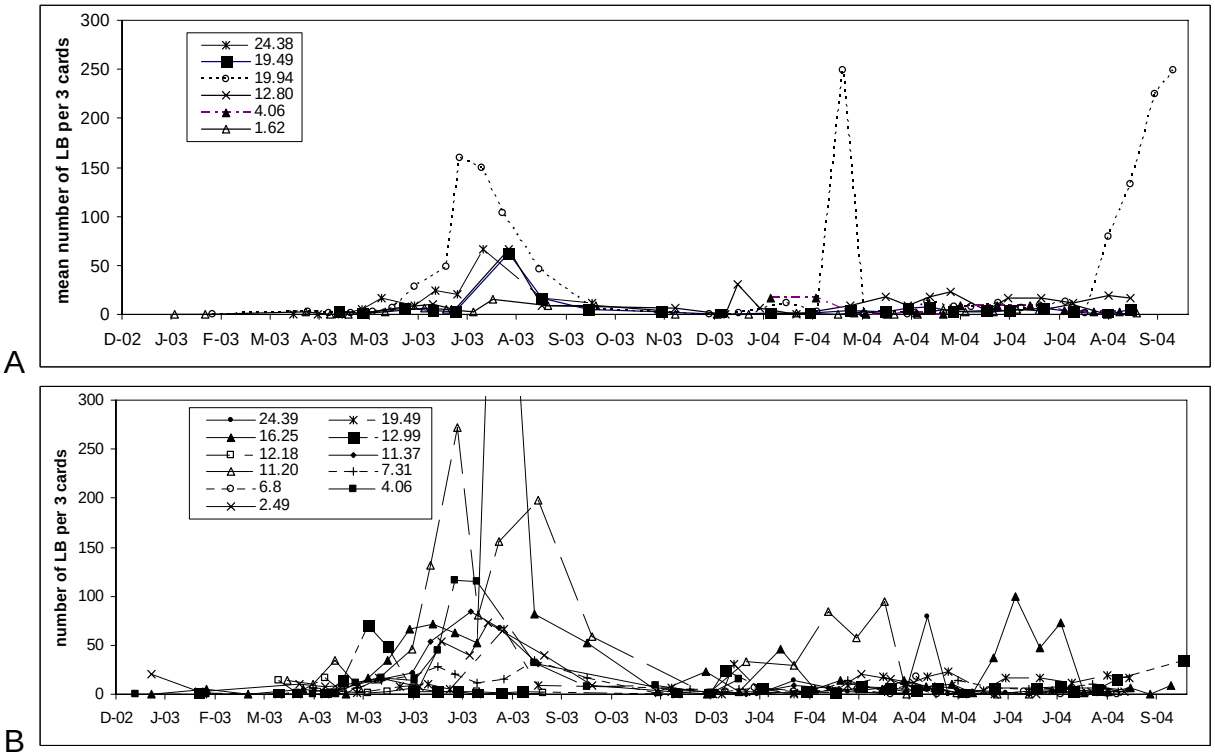

Figure 10. *Mean number of ladybeetles (Coccinellidae species) trapped per 3 sticky cards per avocado grove in Ventura County in 2003 and 2004 (A conventionally treated groves; B untreated groves; locations by distance in miles from the coast).*

The intra-guild relationships between these thrips NE and predatory thrips are not known, but CM and PB are likely to use both the herbivore AT and the predatory species. With the higher numbers of AT in the groves, predatory thrips are probably less important than CM and PB. Large numbers, such as recorded for CM, will contribute to the suppression of AT populations in untreated groves.

Natural Enemies 3: Generalist Predatory Beetles and Lacewings

Natural enemies that are often considered aphid specialists (ladybeetles LB; lacewings LW) or spider mite specialists (*Stethorus picipes,* ST) have occasionally been observed feeding on second and first instar immature AT respectively in the groves. Their numbers are not affected by AT treatments and although they may aid in the natural suppression of AT numbers in untreated groves, their contribution is probably marginal (Figures 10AB, 11AB, 12AB).

Correlations between distance from the coast and LB numbers were not significant in 2003 (F=0.89, *P*=0.3588) nor 2004 (F=1.02, *P*=0.3279). For LW no correlations were significant in 2003 (F=0.43, *P*=0.5236). In 2004 the number of LW trapped on sticky cards decreased with distance from the coast: F=5.58, *P*=0.031, Linear relationship: LW= 1.56-0.0626*distance from the coast in miles; (R^2=25.87, correlation coefficient = -0.5087). For ST no correlations were significant in 2003 (F=0.37, *P*=0.5526). In 2004 the number of ST trapped on sticky cards decreased with distance from the coast: F=8.98, *P*=0.0085, Linear relationship: ST= 2.15-0.856*distance from the coast in miles (R^2=35.95, correlation coefficient = 0.5996).

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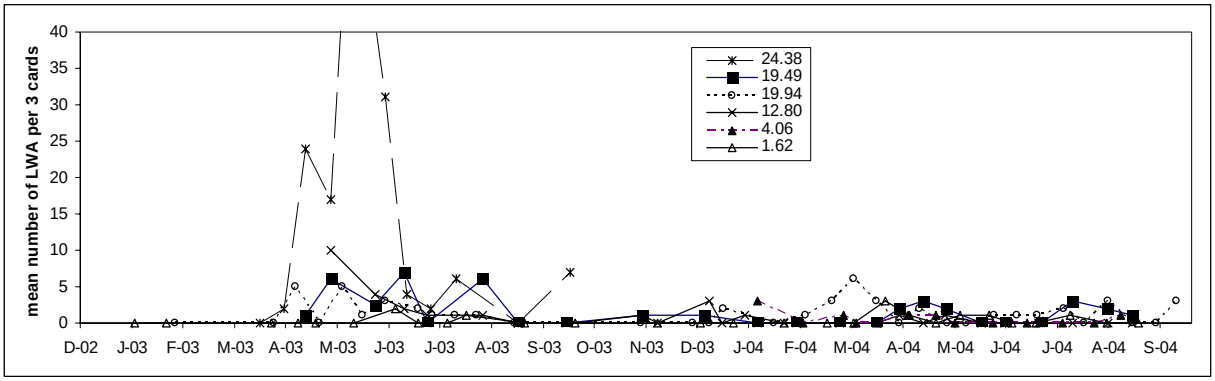

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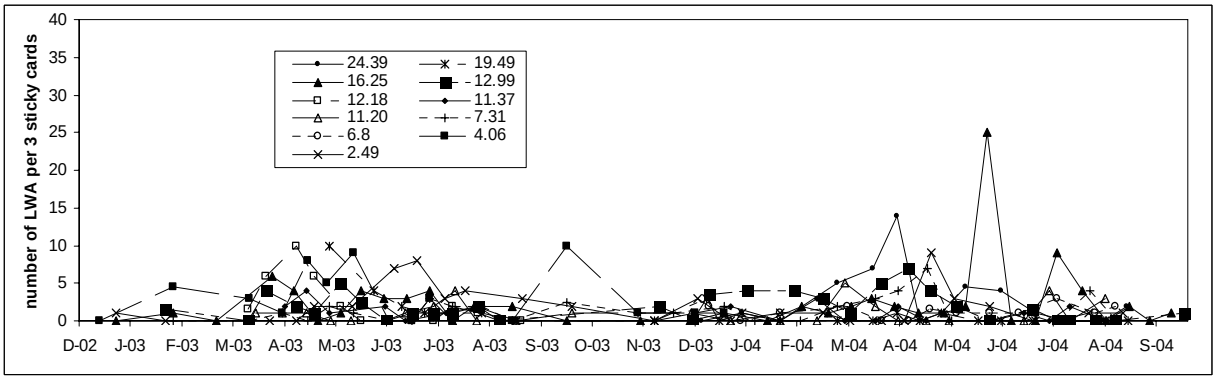

Figure 11. *Mean number of lacewings (*Chrysopa *species) trapped per 3 sticky cards per avocado grove in Ventura County in 2003 and 2004 (A conventionally treated groves; B untreated groves; locations by distance in miles from the coast).*

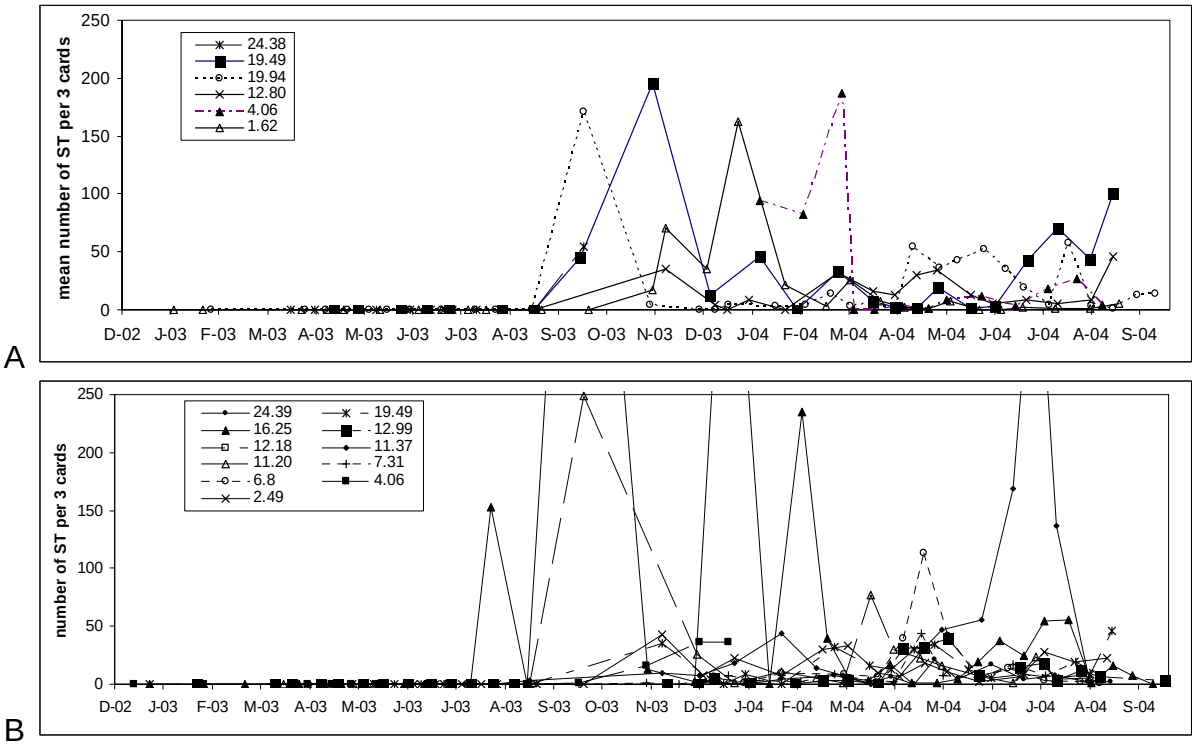

Figure 12. *Mean number of* Stethorus picipes *(spidermite destroyer) trapped per 3 sticky cards per avocado grove in Ventura County in 2003 and 2004 (A conventionally treated groves; B untreated groves; locations by distance in miles from the coast).*

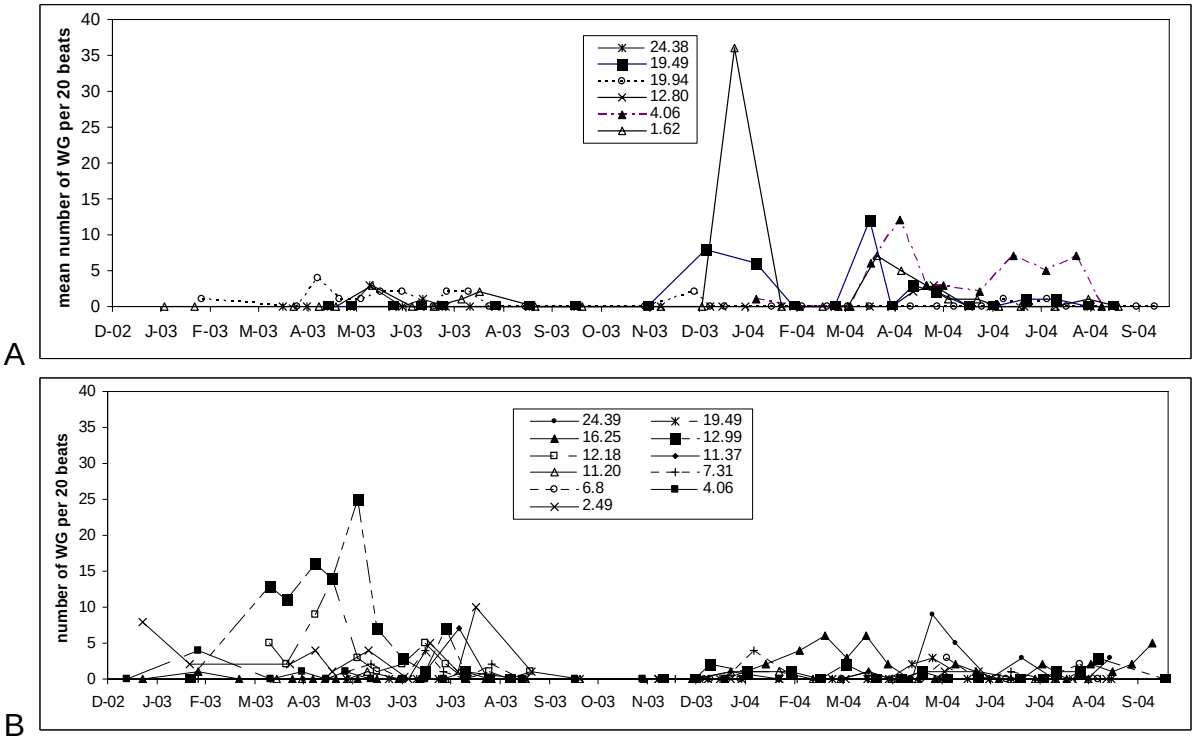

Figure 13. *Mean number of Whirly Gigs (Anestidae) found in 20 beat samples per avocado grove in Ventura County in 2003 and 2004 (A conventionally treated groves; B untreated groves; locations by distance in miles from the coast).*

Natural Enemies 4: Arachnidae

Whirly gigs (WG) (Anystid mites) were present in low numbers in treated and untreated groves throughout the year in 2003 and 2004 (Figure 13AB), no correlations were found that fit the number of WG and distance from the coast.

The spiders (SP) were also present throughout the year in treated and untreated groves in 2003 and 2004 (Figure 14AB). A significant relationship between their numbers and the distance from the coast was found in both 2003 [(F= 4.85, *P*=0.0427, square root Y: SP= (1.389-0.022*distance from the coast in miles)^2, R^2=23.26, correlation coefficient = -0.4822)] and 2004 (F= 9.53, *P*=0.0071, Linear: SP= 0.937-0.09025*distance from the coast in miles, R^2=37.32, correlation coefficient = -0.6109), which means that in both years spiders were more abundant near the coast.

Arachnids are part of the NE population in groves, but their low numbers are unlikely to have a large impact on the AT population.

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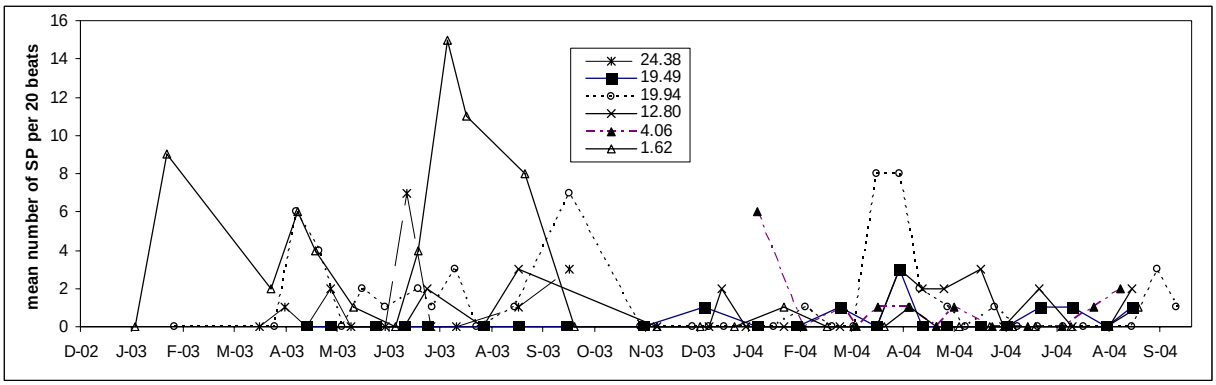

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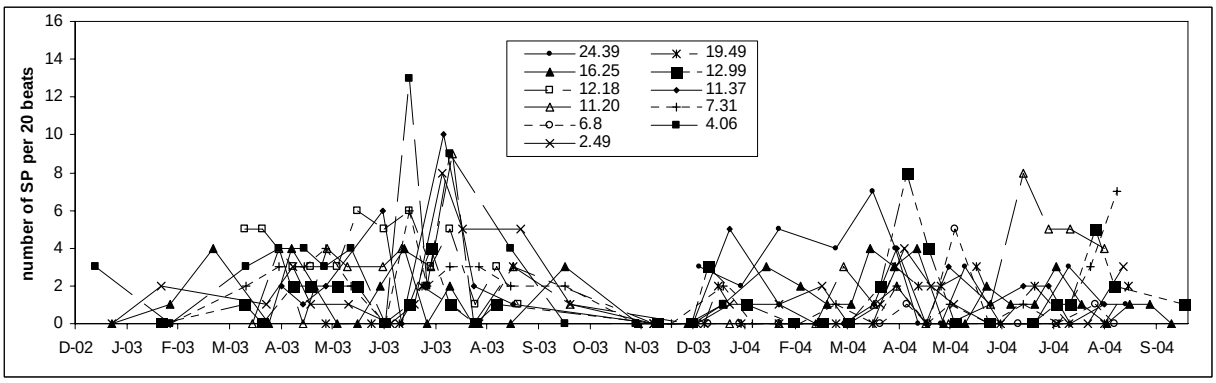

Figure 14. *Mean number of spiders found in 20 beat samples per avocado grove in Ventura County in 2003 and 2004 (A conventionally treated groves; B untreated groves; locations by distance in miles from the coast).*

Orchard floor cover

Correlations between the NE species present in untreated groves and the status of the orchard floor yielded significant relationships (*P*<0.05) in 2003 for LM and LB (increasing), PB and LW (decreasing) and in 2004 for LM and CM (increasing) numbers with increasing fraction floor cover. In 2003, for BH (increasing) and PB, CM, ST (decreasing) and in 2004 for LB (increasing) and LM, PB, CM (decreasing) numbers with increasing fraction living

cover. In 2003, for CM (decreasing) and in 2004, for FT (increasing) and LB (decreasing) numbers with increasing fraction flowering cover.

None of these correlations indicated relationships that exceeded R^2=5, which means that no more than 5% of the data are accurately calculated even though the model fits significantly. The correlation coefficient of these models never exceeded ±0.3 which also indicates weak relationships. Annual differences also confirm the weakness of the relationships. This indicates that groundcover may have some effect on NE numbers, but the data from this study are insufficient to make any recommendations on the use of groundcover in untreated groves.

The relationships between individual plant or weed species present in the ground cover and NE species was too diverse in each grove, and analyses showed no correlations at the species level.

Conclusions

In untreated groves, a higher abundance of natural enemy species was recorded, of which FT, BH and CM and to a lesser degree LM and PB may contribute to the delay in AT population development in spring and suppression of AT numbers in these untreated groves. As a result, the number of fruit set on trees in the observed untreated groves did not differ significantly nor did fruit surface scarring from fruit set on trees in groves treated with abamectin for AT. (Note: This survey did not study the difference in mature high yielding groves, but in relatively young groves or recently stumped or severely pruned groves). Although several NE species can potentially contribute to the suppression of AT numbers, the survey does not indicate any one potential candidate for use in commercial biological control of AT in avocado groves. No one observed NE species is solely responsive for the AT numbers observed.

For some NE species the presence of ground cover on the orchard floor is supporting higher numbers, although no clear recommendations can be given because of the variation of these relationships between the two observed years. Most NE species are found along the coast and in inland locations, but CM, ST, SP and LW are more abundant in locations closer to the coast. The differences between 2003 and 2004 may indicate that results of weather differences are more important than location.

This study highlighted the diversity and complexity of NE population in untreated avocado groves and showed the apparent effect they can have on AT problems in untreated groves. This will hopefully show growers that use of chemical treatments is not always warranted.

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