Contract Title

"AREAWIDE MANAGEMENT OF CODLING MOTH IN MENDOCINO ORCHARDS: INTEGRATING AND MAINTAINING BENEFITS OF SELECTIVE CONTROL OF SECONDARY PESTS"

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ABSTRACT

Codling moth mating disruption was implemented in large-scale plots in the pear district of Mendocino County. In 1998 we increased the acreage under mating disruption by 350 for a total of 900 acres and in 1999 by 150 acres for a total of 1050 acres. Organophosphate use for codling moth control was reduced by 82% in 1998 and 95% in 1999. Damage at harvest ranged from 0 to 0.4% in both years. There was a slight increase in leafroller damage. In field-replicated trials both mites and psylla experienced a statistically significant increase in populations after two applications of the organophosphate methyl parathion. Five acaricides were tested for susceptibility against 3-5 colonies of spider mites collected from 2 distinct regions. Three acaricides (hexakis, abamectin, and clofentezine) showed statistically significant variation between the regions, but the general pattern was very consistent between the 3 acaricides. Resistance levels were always the least for the Sacramento delta populations, whereas colonies collected from North Coast counties were the only populations with significant resistance. No significant variation was observed for hexythiazox or pyridaben between any colony tested.

EXECUTIVE SUMMARY

A strong implementation program was started in Mendocino County in 1996 to facilitate and broaden the adoption of codling moth mating disruption, and to reduce the amount of organophosphate used for codling moth control. A barrier to mating disruption implementation is the high cost of the pheromone dispensers. Savings can be achieved by reducing pesticide use for secondary pests associated with not disrupting an orchard with broad-spectrum materials. Development of soft programs for secondary pests includes the use of selective materials such as abamectin, a microbial by-product. There are some indications that spider mites in pear orchards are developing resistance to this chemical. The aim of this project was to study the benefits of reducing use of organophosphate on spider mites, and the predatory complex controlling them.

We also looked at the susceptibility of spider mites to the acaricides currently registered in pears in an effort to implement a resistance management program to preserve the softer acaricides. Thus the objectives were: 1) to implement areawide management of codling moth with pheromone mating disruption; 2) to demonstrate the effects of organophosphate sprays on spider mite populations and the predatory complex controlling them; 3) to develop resistance management strategy for spider mites so as to maintain selective options; and 4) to develop extension tools and information transfer for implementing spider mite management protocols in areawide programs.

In 1998 we increased the acreage under pheromone confusion by 350 for a total of 900 acres and in 1999 by 150 acres for a total of 1050 acres. In 1998 and 1999 organophosphate use for codling moth control was reduced by 82 and 95% respectively. Codling moth populations and damage continued to decline. Leafroller populations and damage increased throughout the project and through the years. During 1999, oblique-banded leafroller damage ranged from 0.1 to 3.2%. There was an increase in boxelder bug damage on the first 10 rows adjacent to the Russian River with the highest damage of 2.5% in the first row.

Sharing data among all participants allowed us to build confidence in monitoring fields under mating disruption both for codling moth and secondary orchard insect pests. In 1999 the Ukiah Valley Pear Grower Coalition was formed. This grower run coalition will continue to manage and coordinate the areawide mating disruption project in the future.

Pair comparison of organophosphate versus no organophosphate treatments were replicated at six orchards. Each orchard replicate had two treatments: 1) no organophosphate sprays 2) two applications of methyl parathion. In this field-replicated trial, both mites and psylla experienced a statistically significant increase in populations after two applications of the organophosphate methyl parathion. One of the benefits of a mating disruption program is that it decreases the chances of disrupting the predator complex and thus lowers the chances that mites may flare up. The decreased use of organophosphate in the mating disruption project has contributed to the elimination of the post-harvest acaricide sprays and a reduction in the in-season rates.

Five acaricides were tested for susceptibility against 3-5 colonies of spider mites collected from 2 distinct regions. Three acaricides (hexakis, abamectin, and clofentezine) showed statistically significant variation between the regions, but the general pattern was very consistent between the 3 acaricides. Resistance levels were always lowest for the Sacramento delta populations, whereas colonies collected from North Coast counties were the only populations with significant resistance. No significant variation was observed for hexythiazox or pyridaben between any colony tested. The first implication is that unchecked use of the first three acaricides may result in the rapid selection of field resistance. However, it needs to be noted, that no correlation between field performance of an acaricide and changes in resistance at these levels have been made. In fact, the resistance ratios were extremely low in some cases at ca. 3 fold. As such, these relatively low levels of resistance may not result in any change in field performance in terms of efficacy. The lack of any observed correlation between the first three compounds and either pyridaben or hexythiazox may mean that rotational programs between the 2 groups of acaricides may help to reduce that rate at which acaricide resistance evolves. Given that these patterns are only correlational, identification of mechanism(s) capable of detoxifying more than one compound will be necessary before any conclusions are drawn about true cross-resistance. Before any program can be recommended, field-testing of changes in resistance programs under a variety of rotational schemes will need to be undertaken.

INTRODUCTION

An areawide management of codling moth using pheromone mating disruption was initiated in Mendocino County in 1996 on 400 contiguous acres of pears. It increased to 550 acres in 1997. University campus-based faculty, Extension personnel, growers and Pest Control Advisors joined the pear industry to develop and implement the project. Grower participation, a key factor for success, was a major criterion in the selection of the site. This grass-roots effort has continued to evolve and grow. A third and fourth year of research and implementation brought into the program a second wave of growers increasing the adoption and thus the chances the program will be continued at the end of the funding.

Adoption of mating disruption requires an increase in the information base for growers because of the novelty of the approach, the increased rates of monitoring required, and the potential for pest outbreaks normally not found in organophosphate dominated systems. In addition, until growers develop confidence in these new techniques, they will continue to perceive them as high risk. This perception of risk sometimes hampers implementation even more than the biological or economic constraints.

Mating disruption applied on a regional scale has provided pear and apple growers with an alternative to frequent organophosphate-based management strategies and an improvement in efficacy compared to single-farm approaches. Areawide management appears to reduce the risk associated with pesticide use and increases the ability of natural enemies to regulate populations of secondary orchard insect pests and thus provides a more sustainable and stable pest management program.

The primary insecticides used for codling moth control were the organophosphates azinphosmethyl, methyl parathion and phosmet. All these organophosphates have been impacted by the implementation of the Food Quality Protection Act of 1996. Mating disruption provides an alternative that can be rapidly adopted if growers are familiar and feel confident with this technique. In addition, management of codling moth in California pear orchards was threatened by the development of low levels of resistance to azinphosmethyl (Varela et al. 1993), the most commonly used organophosphate in pears. Failure to achieve commercially acceptable levels of control using common rates and numbers of applications resulted in increased azinphosmethyl rates per application and increased numbers of sprayings to control codling moth. This resulted in increased risk to farm workers and increased mortality to natural enemies, leading in turn to secondary pest outbreaks and increasing dependency on pesticides.

The initial goals of the areawide codling moth mating disruption implementation project were: 1) to reduce organophosphate insecticide use by 75% 2) to develop educational programs addressing specific problems and benefits of mating disruption 3) to foster a grower run and supported coalition focusing on soft alternatives in agriculture 4) to provide technical support to growers during the years of transition to pheromone based control programs and 5) to demonstrate the larger benefits of re-structuring pest management of codling moth for reducing pesticides for secondary pests.

In the initial two years of mating disruption in Mendocino County (1996 and 1997), organophosphate use for codling moth control was reduced by 66% and 85% respectively. With an intensive monitoring regimen, we were able to predict and control codling moth "hot spots". There was a slight increase in leafroller damage. Pests of increased concern were various true bugs, including boxelder, lygus and stinkbugs. The largest damage was observed in the rows adjacent to the Russian River. Weeds and shrubs alongside the affected orchards are thought to be the source of these true bugs.

Spider mite damage varied greatly between years and between different sites in the initial years of the Mendocino project. These variations might be due to the initial spider mite population level at the beginning of the season, environmental and climatic factors, the complex of predators present and the amount of disruption that pesticides have on the system. We hypothesized that conditions under mating disruption were more favorable for integrated control of secondary pests and thus a lower probability that the threshold levels for mite outbreaks would be exceeded. Preliminary data from area-wide projects in northwestern states (Westigard et al, 1984a, b, c, 1986) showed significantly higher populations of psylla and spider mites in conventional blocks as compared to mating disruption blocks. In these studies, they also found greater numbers of predatory mites in the mating disruption blocks as compared to the commercial blocks. One of the greatest obstacles currently facing the large-scale implementation and adoption of pheromone mating disruption in pear orchards in California is the initial cost. Current estimates suggest that pheromone mating disruption is approximately $1 00- 125 more expensive than full organophosphate programs. However, these analyses do not consider the potential benefits of reduced pesticide costs associated with not disrupting an orchard with broad-spectrum materials. Preliminary data suggests that after three years the overall costs declined to levels comparable to those of organophosphate based programs. In our study we looked at the disruptive effects of applying two cover sprays of methyl parathion on spider mites and its predatory complex.

As mentioned above, one of the most significant benefits of the mating disruption program is the potential for increased reliance of natural enemies for control of secondary pests. However, this reliance on natural enemies requires the confidence that supplemental control tactics such as acaricides can be used as rescue treatments if natural enemies fail to provide adequate control. Resistance has been documented in the past to a broad array of acaricides in California pears. After eight years of abamectin use in pears, dosage and applications have increased and in 1996 we obtained poor mite control despite increased dosages. The evolution of resistance threatens to undermine the selective use of acaricides and often results in higher rates and more frequent applications that are associated with decreasing spray thresholds. Therefore, development of an integrated resistance management program will allow growers to maintain acaricide efficacy if rational sequences can be employed as part of an overall program that minimizes acaricide use. Work done by Flexner et al. (1988, 1989, and 1995) showed mite resistance to acaricides can be delayed by applying them in a rotational sequence. To manage resistance, we need to understand the effectiveness and potential cross resistance of presently registered acaricides and acaricides with impending registration in pears. Through laboratory bioassays, we evaluated the effects of acaricides on spider mite populations.

WORK PLAN AND METHODS

Implementation of areawide management of codling moth with pheromone mating disruption in Mendocino County pear orchards

Pheromone mating disruption was used as the key technique for managing codling moth. In 1998 one application of the dispenser Bio-Control Isomate-C+ (400dispensers/acre) was applied on 900 acres of pears the first week of April. A second application of the dispensers was placed on only 565 acres on the first week of June at approximately 900 degree-days for codling moth development. For the second application we applied the dispenser at 1/2 the rate (200 dispensers/acre) in an effort to reduce cost (see Table 1B). In 1999, one application of BioControl Isomate-C+ dispensers at a rate of 400 dispensers per acre was applied to 30% of 1050 acres. The other 70% of the acreage received two applications (at biofix and at 900 degree-days) of Concept Checkmate dispensers at a rate of 160 dispensers per acre.

The groundwork for implementing this project was initiated in 1996 with a combination program of mating disruption and azinphosmethyl use to reduce existing population levels. Based on this experience, supplemental sprays were only applied to those orchards that had high moth counts determined by codling moth trap catches. In 1998, 22% and 17% of the acreage received one cover and two cover sprays, respectively. The remainder 6 1% received no cover sprays. In 1999, 26% and 1% of the acreage received one and two sprays, respectively. The remainder 73% received no cover spray.

Program efficacy was determined by fruit evaluations three times during the growing season (preceding 2nd application of pheromone, and during the first and second harvest). Approximately 40 sites were selected within the project based on 40 acres per site. Depending on the site layout, 1000 to 2000 fruit per site (10 from top and 10 from bottom per tree) were selected from each site and scored for fruit injury from both codling moth and potential secondary pests. Five percent of the fruit was cut to look for cryptic infestations. For the final two harvests, bin samples were taken every 40 acres at 1000 fruit per sample. We recorded damage made by codling moth, leafrollers, stinkbugs, and Lygus.

Weekly monitoring for codling moth relied on pheromone traps baited with 10 times the normal rate of pheromone and placed high in the tree canopy. Pheromones trap were placed throughout the project at a rate of 3 traps per 10 acres. Extra traps were placed at the borders of the project and near packing sheds and bins in storage. In addition, one trap for every 20 acres was baited with a 1-mg codlemone lure.

Effects of organophosphate sprays on spider mite populations and its predatory complex

The pair comparison OP versus no OP treatments was replicated at 6 sites. Two treatments were applied at each of the six orchards in the areawide mating disruption project: 1) no organophosphate sprays, and 2) two applications of the organophosphate methyl parathion at the rate of 6 pt/acre. Each plot was half an acre in size.

We sampled for mite populations at pre-bloom and post-bloom by brushing leafs and counting two-spotted spider mites (*Tetranychus urticae*) and Western predatory mites (*Galendromus occidentalis*). We took a bi-weekly sample of twenty shoots (one per tree) per block. Five leaves from each shoot were brushed in a leaf brushing machine and spider mites and predatory mites counted. Psylla nymphs and psylla eggs were also counted. Prior to brushing the leaf, each shoot was examined with a hand lens for number of spider mites per leaf and percent of leaf infested per shoot. This allowed us to compare the monitoring technique done by the PCA's against the brushing sample. An acaricide was applied when mites reach 2 mites per leaf and the experiment was terminated.

Data was analyzed using two-factor repeated-measures ANOVA for insect abundance, with treatment and location as the factors. Separate analyses were performed for two-spotted mites, psylla nymphs and psylla eggs abundance.

Develop resistance management strategy for spider mites so as to maintain selective options

Two-spotted spider mites (*Tetranychus urticae*) were collected from pear orchards during the 1997 and 1998 growing seasons and used to start laboratory colonies. Each colony was used to develop dose response lines for abamectin (Agri-Mek 0.15EC), hexakis (Vendex 50W), pyridaben (Pyramite 50W) and hexythiazox (Savey 50WP). Whereas all 5 colonies were tested against clofentezine (Apollo (42% SC)), only 3 colonies provided statistically significant probit lines.

Colony sources. Three colonies were collected from pear orchards in Mendocino County, CA during June - August, 1997, and are referred to as Ukiah, Mendocino 1 and Mendocino 2 colonies. Two colonies were collected from pear ranches in the Sacramento River delta region near Courtland, CA during October, 1997 and August, 1998, and are referred to as Tower and BK, respectively.

Colony maintenance. Field collected mites were transferred to pinto bean plants (*Phaseolus vulgaris*) and reared in cages in a greenhouse until populations reached adequate numbers for testing. Beans were grown in plastic bags filled with vermiculite. The mite colonies were reared at green house temperatures of 65-90°F and a 16:8 (light: dark) photoperiod.

Bioassay procedures. Leaf disks that were 2 cm in diameter were cut and placed bottom side up on wet cotton placed in 1 oz. plastic cups (Solo ®), a single disk per cup. Adult mortality assays were conducted by transferring a minimum of 20 adult female mites by fine camel-hair brush from bean leaves to each leaf disk. Five replicates with a minimum of 100 mites were transferred for each dose of a given bioassay. Eggs for the egg bioassays (hexythiazox) were obtained by transferring 10 adult females to each leaf disk, and removing them after a twenty-four hour oviposition period, so that only 0-24-hour old eggs remained on the disks.

Dose response to abamectin (Agri-Mek 0.15EC) was evaluated over a six concentration series plus a water only control. The following dilutions were made in water: 1 .0, 0.3, 0.1, 0.03, 0.01, and 0.001 mg AI/liter. Solutions were applied by Potter Spray Tower (see below). Dose response to hexakis (Vendex 50W) was evaluated over a six concentration series (3000, 1000, 300, 100, 30, 10 mg AI/liter) plus a water only control. Earlier trials included a 3-mg AI/L but not the 3000-mg AI/L doses. Pyridaben (Pyrimite 60WP) dose response lines were obtained based on a six dose series (3000, 1000,300, 100, 30, 10 mg AI/L) plus the water control. Hexythiazox (Savey 50WP) dose response lines were based on a five-dose series plus water control (30, 10, 3, 1 and 0.3 mg AI/L). Clofentezine (Apollo) dose response lines were based on a series of six doses (0.03, 0.1, 0.3, 1 .O, 3.0, 10 ppm) plus a water control using the same methodology as hexythiazox.

Extension tools and information transfer for implementing spider mite management protocols in area-wide programs

Weekly mite sampling data and codling moth trap counts were faxed to all participants of the project. Data collected by the PCAs was summarized and shared with all participants. Weekly one-hour meetings were held with PCAs, project coordinator and interested growers to discuss data and management practices. The grower or PCA made all pest management decisions. The project coordinator presented field days and tours during the growing season and a fall meeting. The field days involved other growers not actively participating in the program. In addition, the project coordinator served as a direct and continuing liaison between campus-based researchers in California, Oregon, and Washington and other project coordinators of areawide mating disruption projects of the Pacific Northwest.

RESULTS

Implementation of area-wide management of codling moth with pheromone mating disruption in Mendocino County pear orchards

In 1998 we increased the acreage under mating disruption by 350 to a total of 900 acres, and in 1999 by 150 for a total of 1050 acres (see Table 1A and Map). Organophosphate use for codling moth control was reduced by 82% in 1998 and 95% in 1999. Reduction was calculated assuming three cover sprays, the average number of cover sprays applied to orchards under organophosphate control in the Ukiah Valley during 1998 and 1999.

In 1998, of the 900 acres under pheromone confusion, 61% (552 acres) received no cover sprays, 22% (196 acres) received 1 cover spray and 17% (13 5 acres) received 2 cover sprays (see Table 1C). All acreage that received two cover sprays was part of the new acreage that joined the project that year. Of the acreage that received one cover spray, 56% (113 acres) was also new acreage into the project. New acreage coming into the project had initial high codling moth populations necessitating supplemental sprays. Of the 550 acres that had been in the project for 1 or 2 years, only 15% received one cover spray. A first cover spray was applied where traps baited with 10X lures exceeded 10 moths/trap/week. A second cover spray, timed for the beginning of the second generation (1100 dd) was applied where trap counts exceeded 15 moths/trap/week. Only the areas displaying a consistent trap catch were sprayed. Of the 1050 acres under pheromone confusion in 1999, 73% (770 acres) received no cover sprays, 26% (270 acres) received 1 cover spray and 1% (10 acres) received 2 cover sprays (see Table 1 C). Of the acreage that received one cover spray 48% (150 acres) was new acreage into the project. In the third and forth years of the project we exceeded the target of 75% reduction based on other areawide projects and the 66 and 85% reduction of our first two years (see Table 1D).

The average codling moth trap catches for the entire project were significantly lower in 1999 than those in 1998 (see Chart 1). Total trap catches decreased from 1996 to 1997. In 1998 we observed an increase in the total trap catches due to high populations in the new acreage entering the project that year (350 acres of 900, see Farm 8 and 9 in Chart 2 and Table 2). Codling moth season-long cumulative trap catches decreased in all blocks (see Chart 2 and Table 2) throughout the life of the project. We tracked codling moth seasonal trends in flight activity and generation development with the 1 OX lures.

In 1998 we detected very low codling moth damage (two sites with 0.01%) in the fruit sampled prior to the second application of pheromone. To verify that trap catches accurately reflected the population of codling moth present and to avoid finding ourselves in the situation of not detecting them with the traps but suffering damage at harvest, we periodically inspected fruit for egg laying and early entries or stings. We also evaluated the tops of the trees with an orchard squirrel in early July in those areas where trap catches or prior assessments indicated codling moth or leafroller populations. Codling moth damage at harvest was very low. Thirty-five of the 44 monitoring sites had no codling moth damage at harvest. Only nine blocks had any detectable codling moth damage, ranging from 0.1 to 0.2%. After three years in the program, the problem blocks (Farm 6, block b and c, see Chart 2) suffered no damage at harvest. These two adjacent blocks had a history of codling moth pressure with 8% damage at harvest in 1995 prior to starting the areawide mating disruption project. Populations of codling moth in these “hot spot” blocks have decreased substantially and we achieved control while reducing the organophosphate (OP) use by over 75%.

In 1999 we detected no codling moth damage in the fruit sampled prior to the second application of pheromone. Codling moth damage at harvest was very low. After four years in the program, the problem blocks (Farm 6, block b and c, see Chart 2) suffered no damage at harvest and no organophosphate (OP) was used this year. Also, populations have decreased in those blocks entering the project in 1998 (see Table 2 & Chart 2).

In 1999, low levels of oblique-banded leafroller infestation (0.1 – 3.2%) were detected in 10 of the 21 sites monitored (48% of blocks sampled). This is an increase from 1996 when no damage was detected; 1997 when one block had 1% infestation; and from 1998 when 32% of the blocks sampled had less than 1% infestation and 9% of the blocks had between 1 and 5% damage. Low-level leafroller damage was detected in Farm 5 and control measures were taken during the second oblique-banded leafroller flight. As in previous years, Boxelder damage was restricted to the first 10 rows from the riparian area. The greatest damage was observed in the rows adjacent to the Russian River with up to 2.5% damage.

Sample BioControl Isomate C+ dispensers were weighed weekly to determine amount of pheromone loss. Dispensers were also sent for chemical analysis twice during the season to verify weight loss. Dispensers lasted 150 days, which covered the entire season until harvest.

Effects of organophosphate sprays on spider mite populations and its predatory complex

At the end of the experiment (July 15), there was a significant increase in mite population on the plots treated with methyl parathion (see Chart 3). Predatory mites were found in very low numbers in both treated and untreated plots. Both psylla nymphs and eggs were statistically higher in the blocks treated with methyl parathion (See Chart 4 and 5). Psylla populations were so high that the experiment was terminated.

Develop resistance management strategy for spider mites so as to maintain selective options

Hexakis (Vendex®), Abamectin (Agri-Mek) and hexythiazox (Savey®) were tested against 5 different strains of spider mites (Table 3). In addition, a newer compound, pyridaben (Pyramite®) that was not originally proposed in the grant proposal was tested against the five colonies. A fifth acaricide, clofentezine was tested against the same five colonies, but only 3 of the colonies produced statistically significant probit lines. Therefore, the total number of acaricides tested against the 5 colonies has been increased to 5 in comparison to the original number proposed of 3 acaricides. By increasing the number of acaricides, the hope is to generate a larger set of management options for growers.

Resistance to hexakis (Vendex®) was noted on several occasions in the past in the North Coast region of California. The general pattern of increased levels of resistance in the Mendocino and Lake county areas compared to the Sacramento Delta area was found again. In general, resistance levels in the delta ranged from 4 1.6 to 109 ppm for the Tower and B&K orchards. In contrast, the orchards, Mendocino 1 and 2 and the Ukiah 1 orchard had resistance levels that ranged from 242.8 to 583.2. Thus resistance ratios were as high as 14 fold for the B&K to Mendo 2 contrast.

What were more disturbing were the levels of abamectin resistance noted in both Mendocino orchards that had experienced field control difficulties in past years. Abamectin resistance ratios of ca. 12 fold were noted in the 2 Mendocino orchards, whereas Ukiah 1 exhibited only a 4.5 fold increase. All two orchards in the Sacramento delta region exhibited similarly low levels of resistance.

Pyridaben (Pyramite) showed non-significant variation in resistance levels across the 5 sites with the highest level being reported in Mendocino 2 at only 3 fold. Similarly, resistance to hexythiazox (Savey) was fairly low with the highest resistance ratio of 2.1. Thus, there appears to be no relationship between abamectin resistance and resistance to hexythiazox for these colonies.

Clofentezine (Apollo) exhibited statistically different levels of resistance among regions. Resistance to clofentezine was noted again in one colony collected from Ukiah, whereas the two colonies without significant probit lines failed to show greater than 40% mortality at the highest dose tested. The failure to generate higher mortality suggests that these colonies will produce resistance levels even greater than the Ukiah colony. While the colonies exhibited statistically significant elevations, the resistance ratio for Ukiah and the BK orchard was less than 2.0.

DISCUSSION

In each of the last three years, springs were very cool. We had only two codling moth generations per year. In warm years we have three generations, which might require the use of supplemental sprays to avoid building codling moth populations. High codling moth populations were detected in wind exposed boarders that had to be treated. Traps baited with 10X lures were appropriate to detect hot spots and to determine when supplemental sprays were needed. Sharing monitoring techniques and data between the project coordinator and PCAs has built confidence in monitoring blocks under pheromone confusion among the private consultants and the growers. In 1999 the Ukiah Valley Pear Grower Coalition was formed. This grower run coalition will continue to manage and coordinate the areawide mating disruption project in the future.

We documented an increase in leafroller populations and damage and an increase in boxelder damage in the first 10 rows adjacent to the riparian vegetation. Cost effective and environmentally sound control strategies for these secondary pests need to be developed.

Both spider mites and psylla populations were stimulated in replicated trials that received two application of the organophosphate methyl parathion. One of the benefits of a mating disruption program is that it decreases the chances of disrupting the predator complex and thus lowers the chances that mites may flare up. In the first year **of the** project (1996) we eliminated the post-harvest application of an acaricide that was required in previous years. Since then, we have begun to decrease the rates of the acaricides applied in season. Better understanding of threshold levels for mite outbreaks under pheromone confusion is needed to be able to lower the rates of acaricides used in season.

The preliminary acaricide susceptibility data are both potentially problematic and potentially very positive. The development of abamectin resistance appears to be following the resistance levels reported in the Pacific Northwest. The correlation between the observed 12-fold level of resistance and any control problems are largely anecdotal and will need to be verified with experimental field testing. However, the potential for resistance to increase becomes more acute as variation in populations becomes more easily demonstrated, the assumption being that if variation can be easily detected, then selection on that variation appears more likely. In addition, the resistance to clofentezine (Apollo), noted in at least one colony, suggests that resistance problems would be expected with time and with high use rates.

The positive side of the data is that not all acaricides are demonstrating the same patterns of resistance. Therefore, rotational programs using hexythiazox or pyridaben may result in non-selecting acaricide regimes, which will in turn delay the evolution of increasing resistance levels. The possibilities exist for development of rotational sequences that should maintain adequate control without undue selection for resistance.

SUMMARY AND CONCLUSIONS

After four years of mating disruption on an areawide scale, codling moth populations and damage at harvest continued to decline. We exceeded our target organophosphate reduction for codling moth control of 75% in the last three years. Oblique-banded leafroller damage has increased throughout the project ranging from 0.1 to 3.2%. The greatest damage due to boxelder bug was observed in the rows adjacent to the Russian River with up to 2.5% damage. Sharing data among all participants allowed us to build confidence in monitoring fields under mating disruption both for codling moth and secondary orchard insect pests.

In a replicated trial, we demonstrated that the use of two applications of the organophosphate methyl parathion stimulated an increase in spider mite and psylla populations. The decrease use of organophosphate in the project has contributed to the elimination of the post-harvest acaricide sprays and a reduction in the in-season rates.

Five acaricides were tested for susceptibility against 3-5 colonies of spider mites collected from 2 distinct regions. Three acaricides (hexakis, abamectin, and clofentezine) showed statistically significant variation between the regions. Resistance levels were always lowest for the Sacramento delta populations, whereas colonies collected from North Coast counties were the only populations with significant resistance. No significant variation was observed for hexythiazox or pyridaben between any colony tested. The possibility exists that rotational management programs between 2 groups of acaricides might produce positive results for reducing the rate at which acaricide resistance evolves. One grouping would include hexakis (Vendex), abamectin (Agri-Mek), and clofentezine (Apollo), whereas hexythiazox (Savey) or pyridaben (Pyrimite) would be in a second group. As such, rotation of acaricides between the 2 groups might prove useful for pear growers. Two types of data are currently lacking for these populations: a) what are the mechanisms of resistance and are these mechanisms interlinked? b) field efficacy of a rotational program on spider mite resistance. As mentioned above, the fact that some of the resistance ratios are very low limits the potential utility of these data for constructing strong conclusions about materials like clofentezine.

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Table 1 - Mendocino areawide pheromone mating disruption project description (19964998)

A) Acres under codling moth mating disruption

	1996	**1997**	**1998**	**1999**
Acres	400	550	900	1050

B) Pheromone dispensers applied

	Ties/acre				
	1996	**1997**	**1998**	**1999**	**1999**
	Isomate-C+	Isomate-C+	Isomate-C+	Isomate-C+[2]	Checkmate[3]
At biofix	400	400	400	400	160
At 900 dd	400	200	200[1]		160

[1] In 550 acres (350 acres received only one application at biofix)
[2] In 30% of the acreage (3 10 acres)
[3] In 70% of the acreage (740 acres)

C) Supplemental organophosphate cover sprays

	% total acreage (No. acres)							
	1996		**1997**		**1998**		**1999**	
No spray			66	(360)	61	(552)	73	(770)
1 spray	70	(282)	16	(90)	22	(196)	26	(270)
2 sprays	17	(68)	18	(100)	17	(152)	1	(10)
3 sprays	5	(20)						
4 sprays	8	(30)						

D) Percent Organophosphate reduction

	1996	**1997**	**1998**	**1999**
% OP reduction	66	85	82	95

Table 2 - Cumulative codling moth male trap catches (1996-1999)

	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Farm 8	Farm 9
1996	1.87	2.07	4.82	n/a	17.49	26.29	n/a	n/a	n/a
1997	1.62	4.49	3.22	n/a	13.37	10.86	16.03	n/a	n/a
1998	7.65	5.62	4.32	4.83	5.66	8.27	7.20	32.93	11.22
1999	3.88	2.20	3.09	1.86	3.06	5.74	5.23	18.80	7.33

n/a = Not applicable. Farms were not in the project that year.

Mendocino Codling Moth Mating Disruption Project

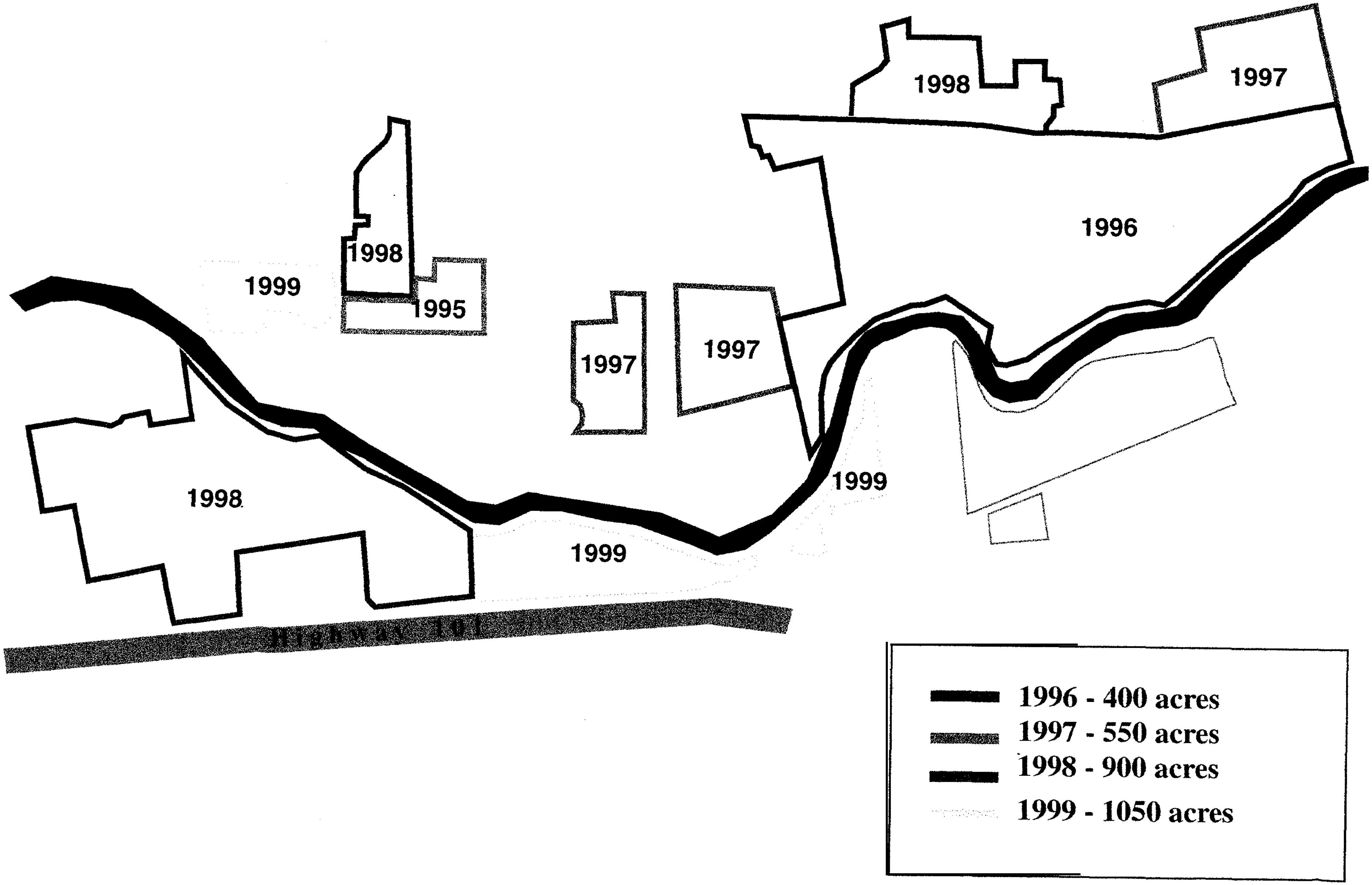

Chart 1 - 1996-1999 Male Codling moth weekly trap catches

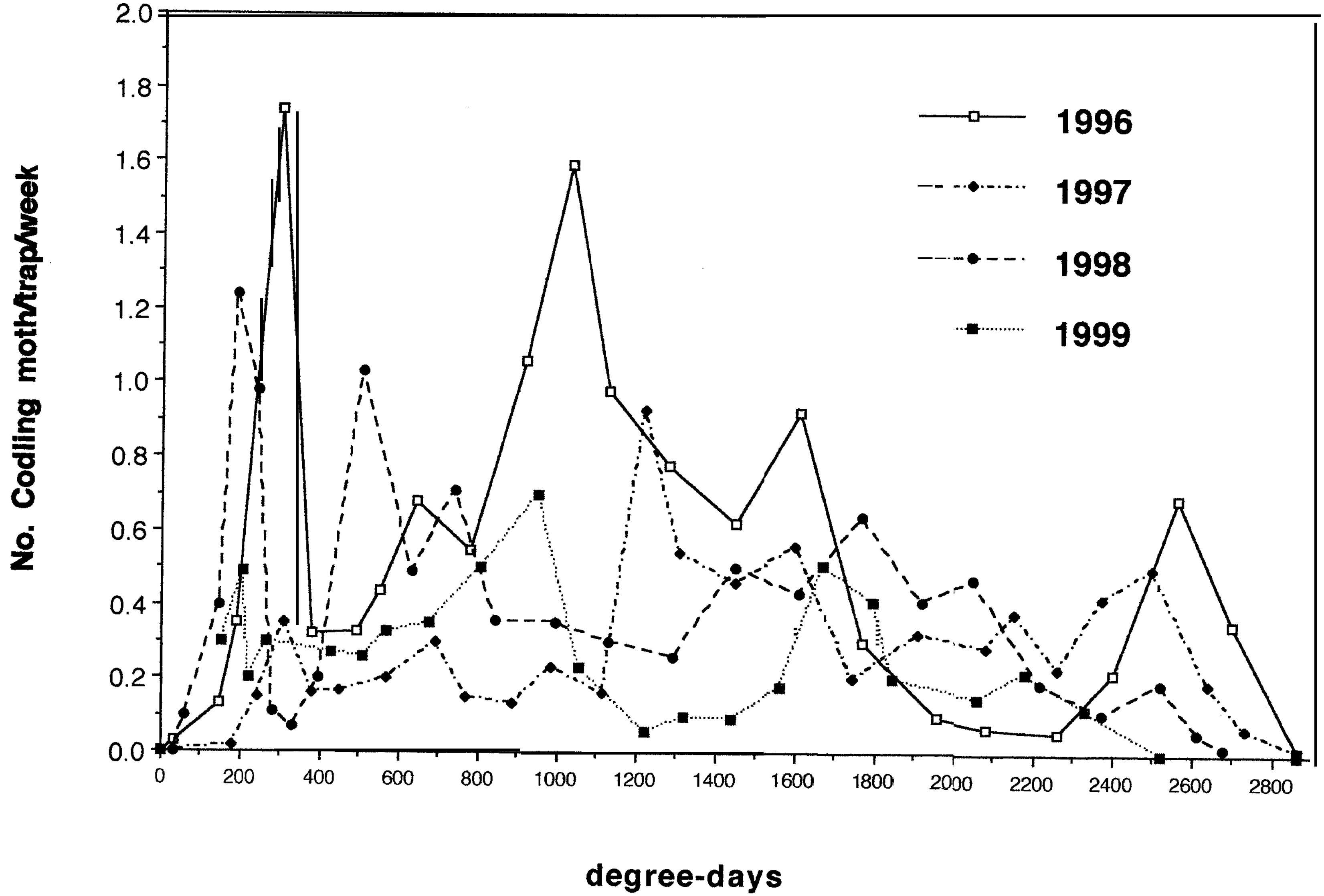

Chart 2 - 1996-1999 Male Codling moth cumulative trap catches by block in each of 9 farms

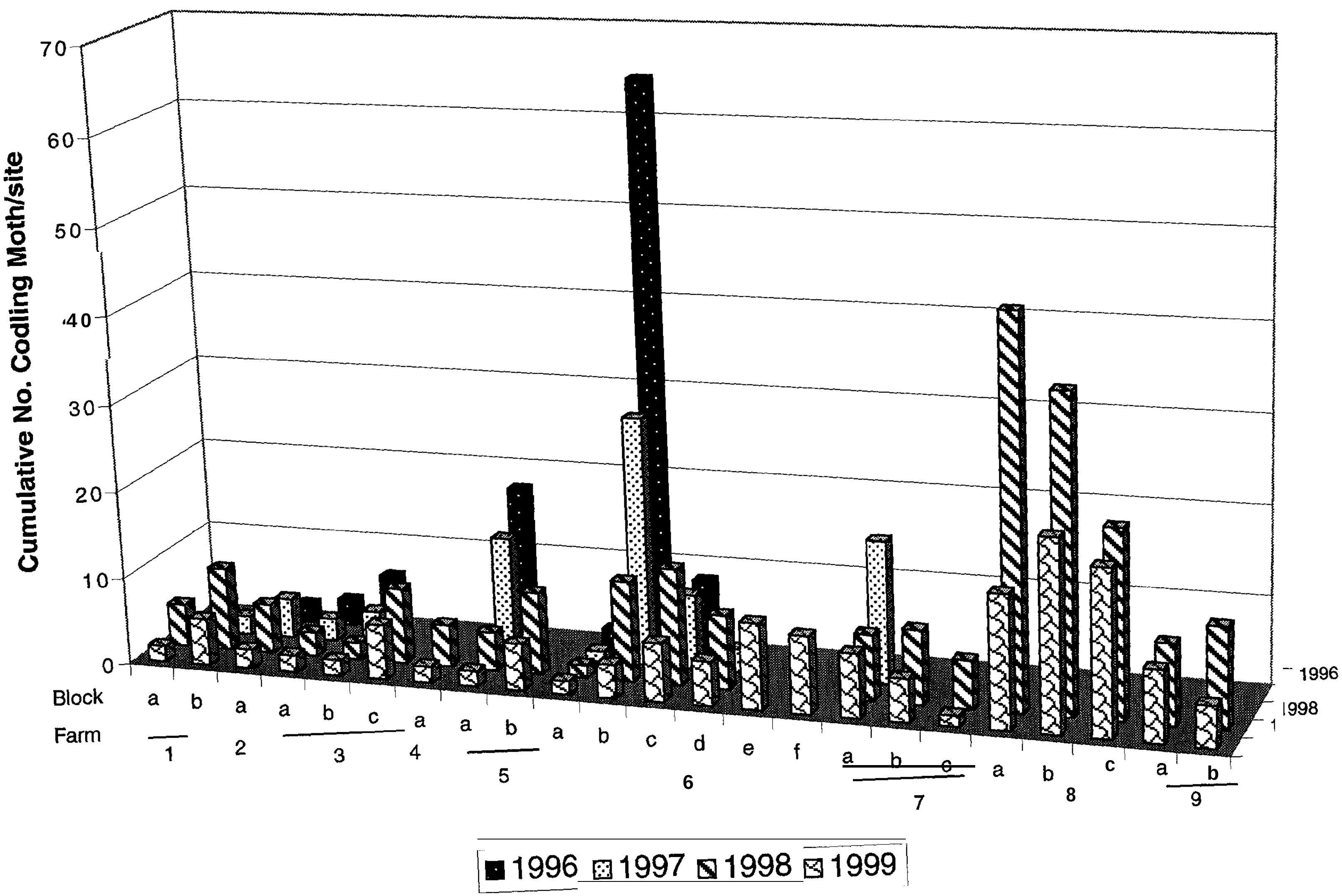

Chart 3 - Number of two-spotted spider mites in organophosphate sprayed plots and non-sprayed plots

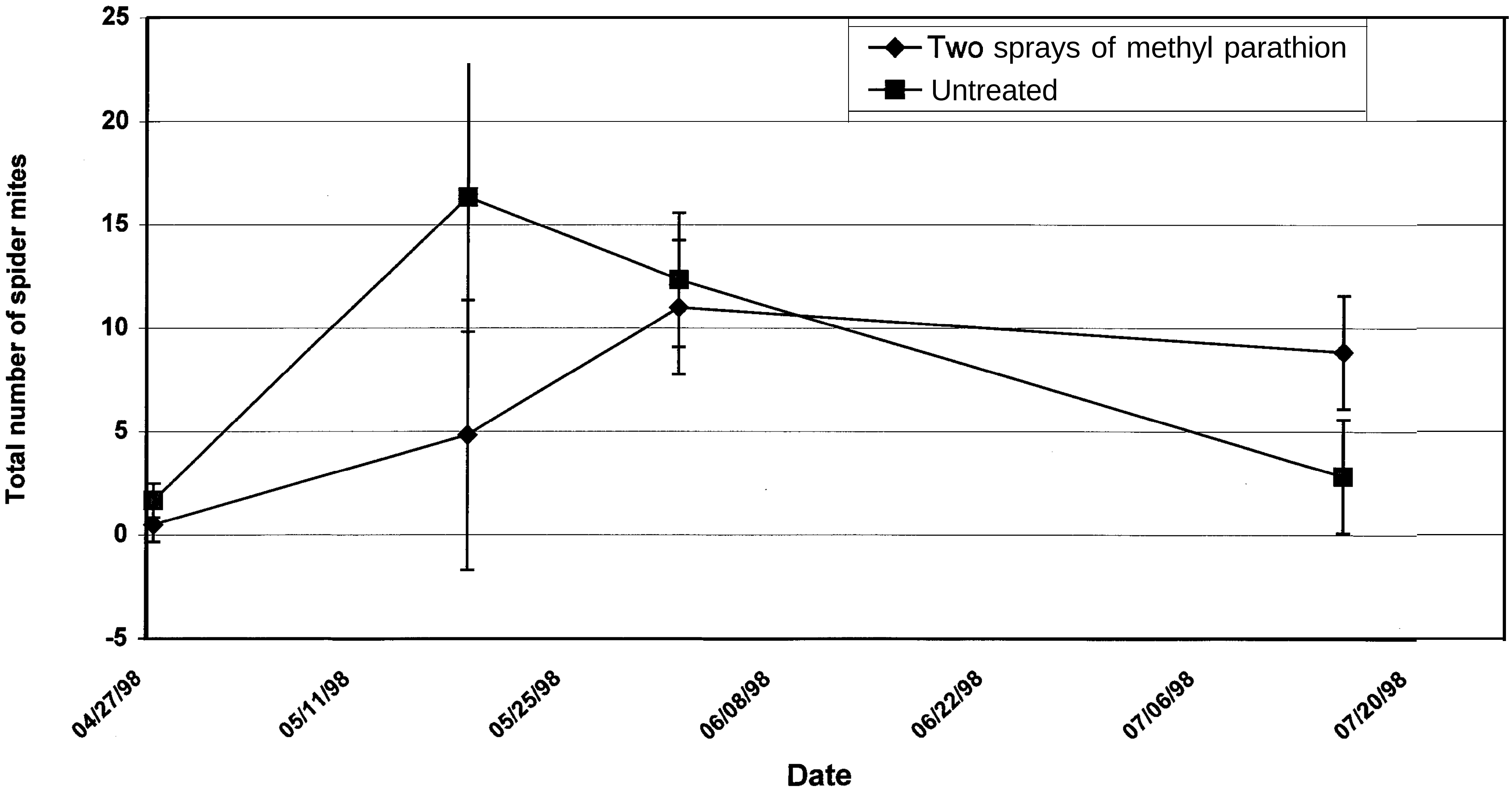

Chart 4- Number of psylla nymphs in organophosphate sprayed plots and non-sprayed plots

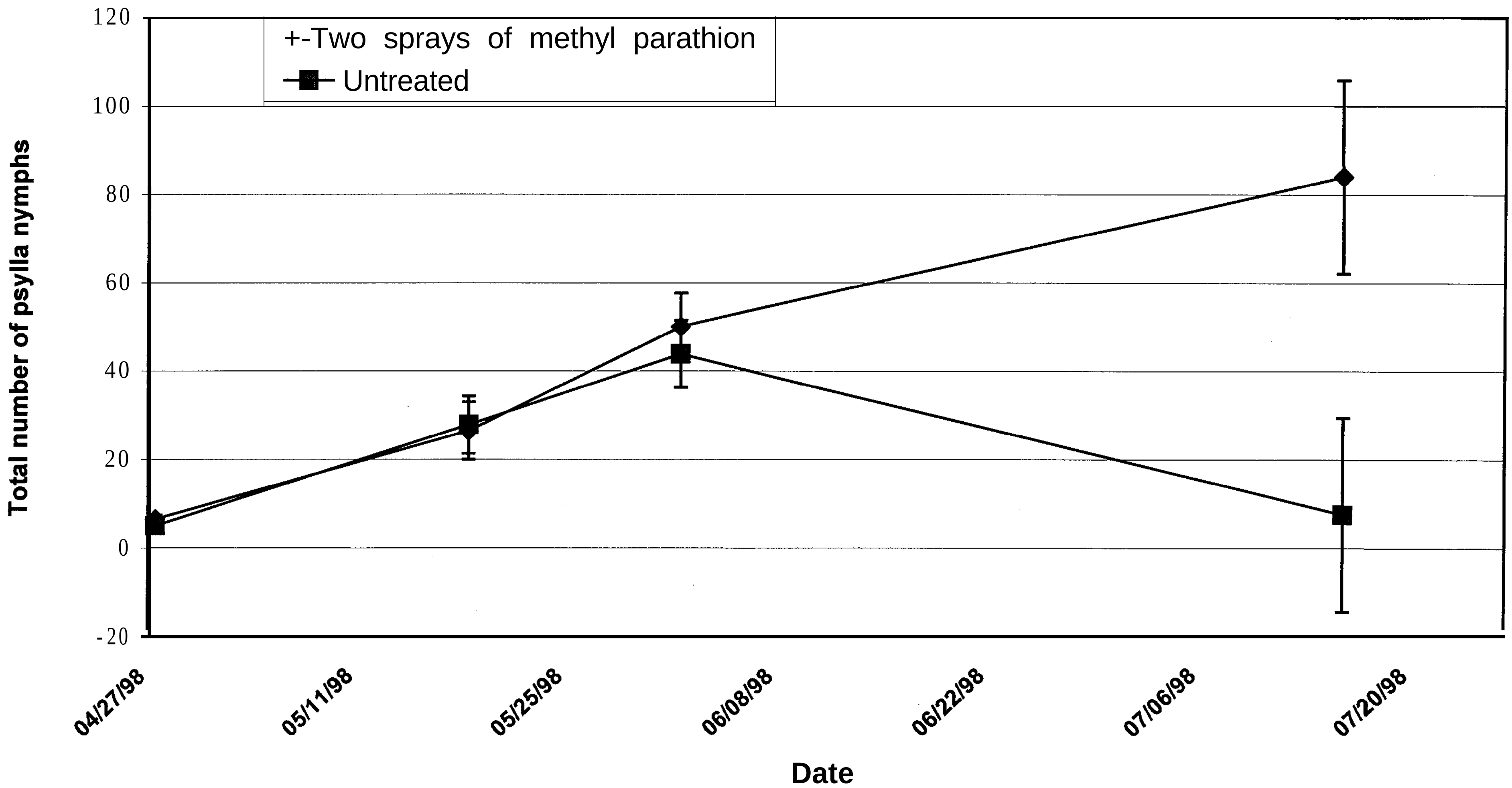

Chart 5- Number of psylla eggs in organophosphate sprayed plots and non-sprayed plots

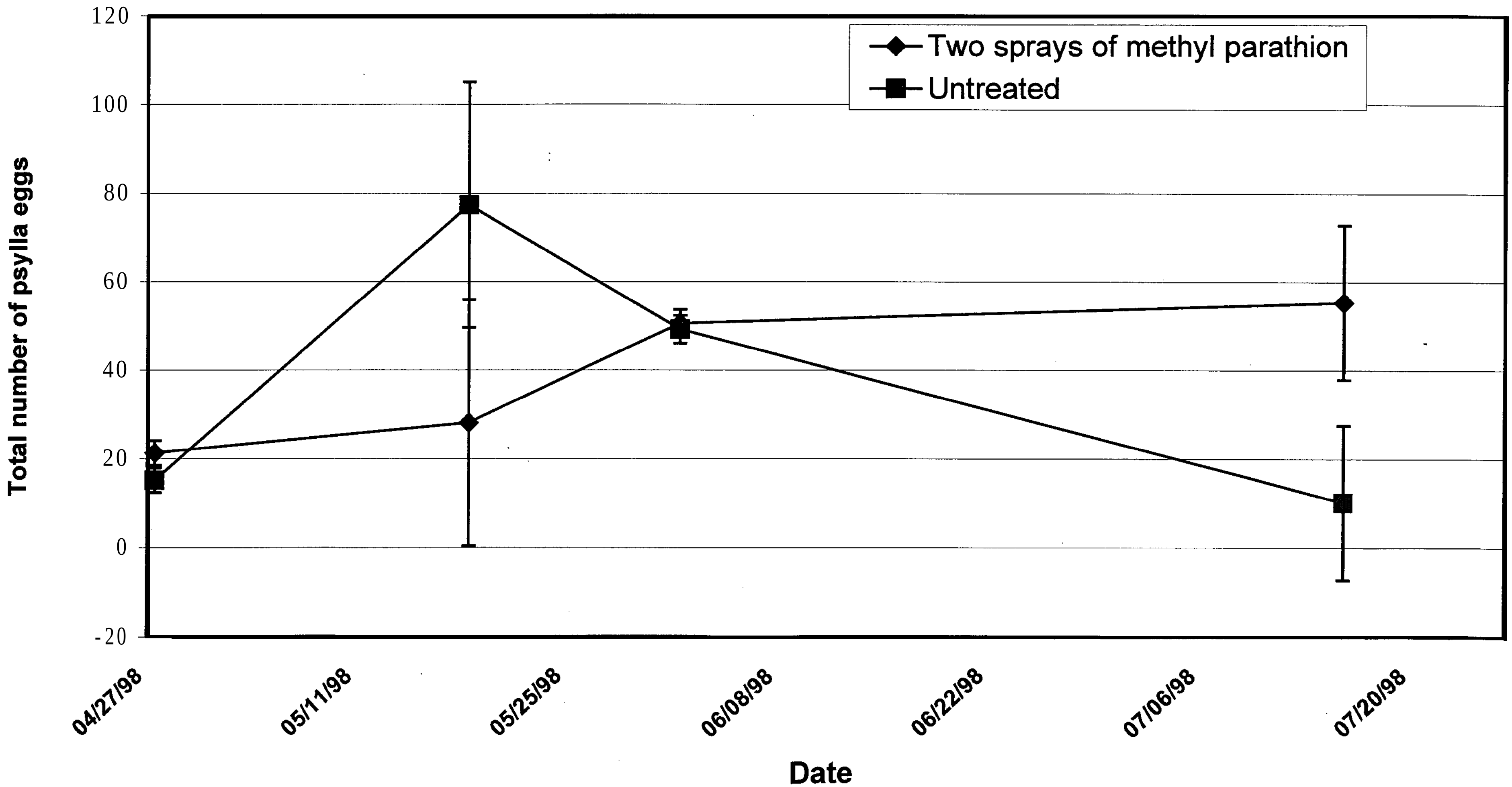

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Table 3. Effects of five acaricides on spider mite populations from 5 locations in California pear orchards.

	HEXYTHIAZOX (Savey 50WP)		**ABAMECTIN (Argi-Mek 0.15EC)**		**PYRIDABEN (Pyramite 60WP)**		**HEXAKIS (Vendex 50WP)**		**CLOFENTEZINE (Apollo 42% SC)**	
COLONY	LD50 (95%CL)	SLOPE	LD50 (95% CL)	SLOPE	LD50 (95% CL)	SLOPE	LD50 (95% CL)	SLOPE	LD50 (95% CL)	SLOPE
TOWER	1.1 (0.9-1.3)	3.354	0.08 (0.02-0.11)	3.369	124.8 (55.3-196.2)	2.204	60.2 (36.3-96.9) 109.0 (80.2-141.7)	3.282 2.544	4.459 (3.45-6.76)	2.516
MENDO 1	1.5 (1.2-1.8)	3.051	0.46 (0.30-0.60)	3.594	159.2 (107.4-217.7)	1.727	532.9 (419.6-656.2) 375.3 (280.6-470.5)	2.854 3.852	24.203* (15.54-63.36	1.686
MENDO 2	1.1 (.9-1.4)	3.045	0.49 (0.31-0.66)	5.23	249.3 (187.6-315.2)	2.822	238.8 (160.1-29.7)	2.234	13.988* (10.67-27.72	2.222
UKIAH 1	2.1 (1.8-2.4)	3.219	0.18 (0.04-0.25)	2.9	93.0 (53.5-142.6)	1.443	242.8 (183.8-353.0) 583.2 (431.6-804.3)	2.851 2.476	7.13 (5.52-9.81)	1.7
B & K	1.1 (.8-1.3) 1.0 (0.9-1.2)	2.685 2.721	0.04 (0.03-0.06)	5.879	82.9 (46.2-126.5)	1.667	61.0 (29.9-83.8) 41.6 (15.6-72.1) 67.0 (45.4-87.3)	3.926 2.253 2.68	3.899 (3.19-4.71)	2.379

* Mortality estimates are preliminary only given that mortality never exceeded 40% even at the highest dose.
Data are only used for further ranging of dose for colony testing