Pest Management Grants Final Report

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Almond biologically integrated orchard systems (BIOS) and conventional almond pest management: A comparative study

Walt Bentley, University of California, Kearney Agricultural Center

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Abstract

Almond growers who use organophosphate, carbamate, and pryrethroid insecticides were compared to those who do not use these broad-spectrum materials in Merced and Stanislaus counties. Results of this study demonstrated consistent but not significantly lower infestation by navel orangeworm and peach twig borer by those that use broad-spectrum sprays. Significantly less (P< 0.10, Fisher's Protected LSD) damage from ants occurred where broad spectrum sprays were used. These differences in average damage were relatively small but the variation in damage was greatest by those not using such sprays. Winter survival of the navel orangeworm parasitoid *Goniozus legneri* and parasitism by this beneficial was low in all orchards, whether sprayed or unsprayed with broad spectrum sprays. Winter removal of unharvested almonds to less than two per tree was demonstrated to reduce infestation by NOW. Although many of the almond growers not using organophosphate or pyrethroid sprays had damage below some that used these materials, the greater <u>range</u> of damage experienced by them may be why more almond growers prefer to annually use these materials to combat insect pests.

Executive Summary

In 1988 farm advisor Lonnie Hendricks began a study where he followed the pest management practices of two brothers, Glenn and Ron Anderson. One managed insects and weeds with a conventional, broad-spectrum pesticide approach. The other used no insecticides, planted a covercrop, and minimally relied on herbicides. Hendricks followed infestation from peach twig borer, *Anarsia lineatella*, and Navel orangeworm, *Amyelois transitella* over a six-year period. He found no differences in infestation due to either of these pests. In fact, damage in the unsprayed orchard was often numerically lower than in the sprayed orchard.

Although some almond growers, such as Ray Eck and Glenn Anderson, had moved away from using organophosphate and carbamate insecticides for many years, the results of the Anderson study intrigued many others who wished to reduce inputs for insect pest management. From this grower interest was born the Almond BIOS (Biologically Integrated Orchard System) program initiated by the Community Alliance with Family Farmers. Many growers however still want the security of broad-spectrum organophosphate and carbamate insecticides in managing almond pests. The risk of damage from omitting sprays is more than they are willing to accept.

In 1996 an intensive study was designed to evaluate elimination of broad-spectrum insecticides on a larger scale than done in the Hendricks study. Information on pest and beneficial insect dynamics as well as nut infestation was taken from orchards that followed two different pest management approaches. A Biologically Integrated Orchard System (BIOS) approach, not using disruptive sprays, was compared to a more conventional pest management system where sprays are used. Also, the BIOS orchards had cover crops planted while only two of the Conventional orchard comparisons used planted cover crops (both low grow mixture). In addition, periodic release of *Goniozus legneri*, the navel orangeworm parasitoid, was made in four of the unsprayed orchards at least once during the study.

The term Conventionally sprayed orchard is used in this study and is based on the practice of either a dormant spray or at least one seasonal insecticide spray. The National Evaluation of Extension's Integrated Pest Management (IPM) Programs, Appendix 2: California Almond IPM Impact Study reported 92 percent of respondents used dormant broad spectrum sprays while over 78 percent used May sprays and over 81 percent used hullsplit sprays (Rajotte et. al., 1987). Using this information, growers that applied these sprays would be termed conventional. This study ran for three years. The four objectives were:

1. Investigate the relationship between winter sanitation and the abundance of *Goniozus legneri* during the winter, and to validate the relationship between winter nut removal and NOW infestation for those who do not spray organophosphates.

2. Evaluate the abundance of San Jose scale and its associated parasitoids in BIOS and Conventionally managed orchards.

3. Monitor NOW and peach twig borer (PTB) throughout the growing season in BIOS and Conventional orchards to determine if there are major differences in abundance and seasonal activity based on management practice.

4. Assess damage due to ants, NOW, and PTB at harvest in BIOS and Conventional orchards and tabulate differences in parasitism between these two practices.

Introduction

The results of this study demonstrated, from Objective 1, that the navel orangeworm parasitoid survival during the winter was very poor, regardless of the level of winter mummies left on the tree. Also winter sanitation was more effective in reducing NOW infestation than any other pest management practice followed by growers in this study. From Objective 2, San Jose scale populations were least abundant in those orchards not using disruptive organophosphates or pyrethroids (only one non-sprayed orchard had damaging San Jose scale populations). Alternatively, the parasitoid *Encarsia perniciosi* was more abundant in those orchards not using disruptive sprays. From Objective 3, there were no differences in the abundance of NOW eggs or male peach twig borer moths per trap per season between the two approaches to managing insect pests. There were also no differences in the initiation of egg laying by NOW or the initiation of male PTB flight for any of the generations of these pests based on pest management practice followed by growers. The greatest nut damage in each year was due to NOW infestation, the least damage due to PTB infestation. There were no significant differences in damage based on pest management practice used by the grower. Ant damage was intermediate between that of NOW and PTB and was significantly less ($P<0.10$, Fisher's Protected LSD) for growers using organophosphate or pyrethroid sprays. There was no statistical difference in the average total damage based on the pest management approach used by these growers, but the range of damage was greater for the BIOS growers.

Materials and Methods

Eight BIOS and eight conventionally sprayed orchards were initially selected and monitored throughout the season beginning in 1996. One of the comparisons was dropped after both sides were sprayed, leaving only seven site comparisons. Two orchard comparisons were located in Stanislaus County and five in Merced County. The delineation of insecticide management practice, as described above, characterizes the orchard comparisons. Due to a range of characteristics such as pollinizer varieties, orchard size, cover crops, and location, the description of the orchard comparisons is presented in Table 1 only. Each of the orchard comparisons was comprised of the Nonpareil cultivar that is quite susceptible to navel orangeworm (NOW). It is the predominant and currently most desirable almond cultivar. In each of these comparisons, with the exception of comparison three, the orchards are side by side. Comparisons two, four and five are part of the same orchard. The orchards in comparison three are 1 mile apart. Orchard seven used no insecticide applications in the conventional plots and is not included in the summary of the Conventional versus BIOS comparison, but is used for the winter sanitation portion of the study. The only difference between management practices in Orchard seven was the planting of a low-grow cover crop in the BIOS side. The conventional plot side had a resident vegetation cover present.

The orchard comparisons are termed either as a BIOS orchard or a conventionally sprayed orchard. Each of the conventionally sprayed sites received either a dormant oil or organophosphate spray for a dormant spray or a “hullsplit” organophosphate spray in July of each year, or both. Two of the Conventional orchard comparisons were not treated in 1997 and data from these two sites were not used during the 1997 year. The conventional comparison in these two sites was sprayed in 1996 and 1998. The BIOS orchards did not receive any broad-spectrum sprays during this study. Some were treated with *Bacillus thuringiensis* (Bt) at bloom to manage PTB and four received releases of *Goniozus legneri* for NOW control. None received dormant sprays.

During the winter of 1996, 1997, and 1998, ten to twenty trees were selected in each orchard and the number of unharvested mummy nuts counted. This information was used to evaluate the influence of winter nut abundance on subsequent NOW infestation. Where possible 50 to 100 nuts were collected from trees and evaluated for NOW infestation and parasitism. As many mummy nuts as possible were collected from the tree (on the ground if not possible to collect from tree) to examine for parasitoids and NOW. Navel orangeworm were also held in storage to document emergence of *Goniozus legneri*. Three of the comparison orchards were not established early enough in 1996 to take mummy counts. However, mummy counts were taken from all the BIOS orchards in each of the three years. In addition, mummy counts were taken from 44 BIOS orchards in 1996 to evaluate winter survival of *Goniozus legneri* where disruptive sprays were not used. None of the 44 orchards used dormant or in season organophosphates or carbamates.

Each of the orchards was monitored for PTB with two Pherocon 1c traps and Consep pheromone dispensers changed every month in 1996. In 1997 and 1998 three traps were used in each orchard. Navel orangeworm dynamics were monitored in 1996 with two black navel orangeworm egg traps baited with almond press cake and almond oil, changed monthly during the growing season or when they became wet. Three traps were used in 1997 and 1998. San Jose scale was monitored with two Pherocon tent traps baited with Trece San Jose scale pheromone dispensers changed monthly. Three San Jose scale traps were used in 1997 and 1998.

At harvest 500 nuts were randomly collected from each orchard with no more than 20 nuts taken from beneath one tree. These were evaluated for NOW, PTB, and ant damage. Also, when NOW were found, they were examined and held in glass vials for parasite emergence.

In addition to the data collected from the intensively managed orchard sites, information on nut infestation was collected from grower grade sheets. This information was collected from only growers enrolled in the BIOS program in Merced and Stanislaus counties. In 1996, 13 Merced almond growers and 12 Stanislaus almond growers provided grade sheets from processors that indicated infestation due to insects. In 1997, nine Merced and ten Stanislaus growers did the same. The infestations were then compared to that of the county averages, as reported in the annual report of the Almond Board of California. This information would give a broad picture of infestation experienced by the growers in the BIOS program, how it related to the county average, and how the participants of this study compared to other BIOS growers. Data was available only for 1996 and 1997.

Results

Objective 1. Figure 1 presents a summary of the average winter mummy load in the BIOS and Conventional comparisons. The data from 1996 does not include one BIOS orchard that had a mummy count of 113 mummies per tree, but was included in harvest infestations. If included, the BIOS mummy count would average 21 per tree. Excluding the mummy count from Orchard 1 results in 2.66 mummies per tree in the BIOS and 1.23 in the Conventional (only four orchards). In 1997, all six comparison orchards were included and the average mummy count was 2.54 in the BIOS orchards and 4.66 in the Conventional. The 1998 counts were the highest of the three years with an average of 5.94 in the BIOS orchards and 5.18 in the conventional. The three-year average mummy loads were 3.7 in both the BIOS and the Conventional. The implementation of winter nut removal was equal between the two groups of growers. University of California guidelines state that two or fewer mummies per tree are the key to managing NOW. Only the four Conventionally managed orchards in 1996 averaged less than two mummies per tree.

The seven BIOS orchards (including the nonsprayed orchard comparison site) were categorized by the number of mummies per tree, in each of the three years. The two broad categories used were orchards with less than two mummies per tree during the winter and those with greater than two mummies per tree. At harvest, nut infestation was then determined for the orchards that fell into the two groups. In 1997 only one of the orchards averaged greater than two mummies (interestingly, 1997 resulted in the lowest infestation from NOW and the smallest difference between BIOS and Conventional grower infestation). This sample is too small to use in statistical analysis. Figure 2 presents the average harvest infestation from orchards in these two categories. Over the three year period the average infestation from orchards with greater than two mummies per tree was 3.90 percent while those with less than two per tree was 2.26 percent which validates previous work showing the benefit of winter sanitation in reducing infestation from NOW. When the mummy counts from each of the BIOS orchards were pooled over the three-year period and a regression analysis performed, a highly significant ($P<0.0001$) R^2 of 0.582 and an R value of 0.766 resulted (23 orchards).

Forty-four BIOS orchards (including the six in the comparison) were evaluated for the presence of NOW and its parasitoid *Goniozus legneri* in mummies in 1996. A total of 2720 mummies were examined and 379 (13.93 percent) were infested with NOW. Four NOW (1.1 percent) were parasitized from these collections. Two of the four parasitoids were *Goniozus legneri* and two were parasitized by *Copidosoma plethorica*. None of the six intensively monitored BIOS orchards were found to have parasitoids in the infested almonds. Similarly, mummy counts and parasitism was evaluated in 1997. Only four BIOS orchards were sampled in 1997. From 400 nuts, 32 nuts (8 %) were infested with NOW. A single (3.1 percent of the infested nuts) *Goniozus legneri* was found. In 1998, nine BIOS orchards were sampled for mummy nuts. A total of 595 mummies were examined and 111 NOW found (18.7 percent). No parasitoids were found in 1998. Over the three-year period 522 NOW were sampled from unharvested mummy nuts in unsprayed orchards. Only 5 parasitoids (3 *Goniozus legneri* and 2 *Copidosoma plethorica*) were found. The results of this study indicate that winter survival of *Goniozus legneri* is very low in Merced and Stanislaus counties.

Objective 2. San Jose scale has become an increasingly damaging pest in many almond-growing areas of California. Yet, almond growers in Stanislaus, Merced, and Madera counties have reported little tree damage from this pest. Results from this study indicate that San Jose scale is not a common problem in either BIOS or Conventionally managed programs in these counties. The abundance of San Jose scale males trapped in San Jose scale sticky traps is correlated to crawler abundance (Bentley et al., 1998). The numbers of SJS trapped in this study were remarkably low, with only one of the BIOS orchards showing symptoms of scale damage (limb death in the lower canopy). This became evident during the third year of the study when traps averaged 707 male SJS during the season. No other BIOS orchard trapped more than 104 SJS. The number of males caught (monitoring three flights) per trap per season averaged 152 over the three-year period in the unsprayed orchards and 524 in the sprayed orchards. Figure 3 presents the data graphically. Due to the high level of variation in trap catches there was not statistical difference in the numbers of scale between the BIOS and the Conventionally sprayed orchards.

There was a significant difference ($P<0.12$, Fisher's Protected LSD), between the numbers of *Encarsia perniciosi* trapped. *Encarsia perniciosi* is a key parasitoid of San Jose Scale and it does appear to be key factor in regulating SJS populations in these orchards. An average of 2750 Encarsia were trapped in the BIOS orchards and 1373 in the conventionally sprayed orchards.

There was no difference between treatments in the number of *Aphytis spp*. trapped on SJS pheromone sticky traps. An average of 231 *Aphytis* spp. per trap were trapped in conventionally sprayed orchards and 216 per trap in the BIOS orchards. *Aphytis* spp. tended to be trapped very early and very late in the season, with few trapped during the months of June and July. Although it would appear that *Encarsia perniciosi* is a more important parasitoid than *Aphytis* spp. this may not be the case. *Aphytis* spp. may respond less well to the synthetic pheromone, while relative abundance is greater. Research on the actual level of parasitism is currently being done.

Objective 3. The abundance of NOW, based on egg counts found on navel orangeworm egg traps, was very low in both the BIOS and Conventionally sprayed orchards. A total of 85 eggs per trap per season were trapped in the BIOS orchards while 118 per trap per season in the Conventional orchards (Figure 4). There was no significant difference in the number of eggs deposited on egg traps between the two comparisons over the three-year period.

The initiation of NOW oviposition on black egg traps was identical between the BIOS and Conventionally sprayed orchards, with no obvious shifts in periods of egg deposition.

The abundance of PTB, based on pheromone trap counts, was not different between the BIOS orchards and the conventionally managed orchards (Figure 4). The average number of PTB per trap per season was 2199 in the BIOS orchards and 2273 in the conventionally sprayed comparison. Also, as with the NOW, PTB flight dynamics were not different between the two treatments. The beginning of male flight in each of the three generations, in each of the three years was identical in the BIOS and Conventionally managed orchards.

Objective 4. Of greatest interest to almond farmers is damage due to ants, NOW, and PTB based on the two management practices in this study. Figure 5 presents the results from infestation due to NOW, PTB, ants, and combined infestation. There was no significant difference between BIOS pest management practices and Conventional pest management practices in infestation due to NOW, PTB, or Total damage. Numerically the three-year average damage due to NOW was 3.36 percent for growers under the BIOS program and 2.35 percent damage for growers using Conventional practices. During each of the three-year years, damage by NOW was least in the Conventionally managed orchards but the variation in damage was greater. For instance, NOW infestation was 4.46, 2.48, and 3.13 per cent for BIOS growers in 1996, 1997, and 1998 respectively. Damage by NOW was 2.23, 2.16, and 2.67 percent for The Conventionally sprayed orchards for the same years, respectively. The variation in damage is much less in the conventionally sprayed orchards than that in the BIOS orchards. The inconsistency of low NOW infestation is one key reason why growers are hesitant to move to a reduced chemical program.

The NOW parasitoid, *Goniozus legneri*, was also sampled when examining nuts for NOW infestation. Only eight parasitized larvae were found over the three-year period in the BIOS orchards at harvest. During 1996, 197 NOW were collected and held for parasitism and four were parasitized by *Goniozus legneri* (2 percent). During 1997, 87 NOW were held for parasitoid emergence and four were found parasitized (4.6 percent) parasitism. No Parasitoids were recovered during 1998 from 125 NOW. During 1996, NOW infestation in the two orchards with parasitoids present was 4.8 percent and 4.4 percent. In 1997, NOW infestation in the two orchards with parasitoids present was 6.2 percent and 5 percent. No *Goniozus legneri* were found in NOW sampled from the Conventionally sprayed orchards.

Although flight by PTB was quite high in all orchards, damage by this pest was minimal. The three-year PTB infestation averaged 0.43 percent in the BIOS orchards and 0.55 percent in the conventionally sprayed orchards. There was no significant difference in PTB damage as influenced by pest management practice. In no year did damage by PTB average more than 1 percent. Interestingly, this is one of the key pest almonds growers attempt to manage with the dormant spray program and may pose less a risk than once believed.

Ant damage, although intermediate between damage from NOW and PTB, was significantly less (P< 0.10, Fishers protected LSD) in the Conventionally managed orchards compared to the BIOS orchards. The three-year average damage due to ants was 1.24 percent in BIOS and 0.67 percent in the conventionally managed orchards.

Total insect damage was not significantly different between the two pest management practices. Total damage in the BIOS orchards averaged 5.03 percent and 3.57 percent in the Conventionally sprayed orchards.

Average county infestation compared to selected BIOS almond growers. A sampling of orchards managed without broad-spectrum sprays (BIOS participants not included in this study) was taken in 1996 and 1997 from both Merced and Stanislaus counties. In Stanislaus County, 12 orchards were sampled in 1996 and 10 in 1997. In Merced County, 13 orchards were sampled in 1996 and 9 in 1997. The average total insect damage found was then compared to the Stanislaus and Merced County average insect damage as reported by the Almond Board of California. The average infestation for the Merced County BIOS orchards was 4.3 percent and 3.3 percent for 1996 and 1997 respectively. The county averages were 2.5 percent and 2.0 percent for 1996 and 1997 respectively. The 1996 Merced BIOS infestations is significantly different from the county average (P<.007, Wilcoxon's sign rank test). The 1997 infestation was not significantly different. The average infestation for the Stanislaus County BIOS orchards was 3.0 and 2.2 percent in 1996 and 1997 respectively. The Stanislaus County average infestation was 2.3 and 1.5 percent in 1996 and 1997 respectively. There was no significant difference between BIOS growers and the Stanislaus County average in either year.

Discussion and Conclusion

The results of the winter sanitation investigation indicate that survival of the parasitoid *Goniozus legneri* was poor, even in unsprayed orchards where mummy loads were quite high. One of the BIOS orchards averaged 113 mummies per tree in 1996 and no wintering parasitoids were found even though 10.4% of mummies were infested with NOW. Alternatively, the practice of winter sanitation resulted in a consistent reduction of NOW infestation at harvest. The practice of not removing and destroying mummy nuts, so as to preserve *Goniozus legneri*, cannot be recommended based on these findings. Where *Goniozus legneri* was found active at harvest, infestation from NOW was relatively high (ranging from 4.4% to 6.8%). Almond growers that wish to supplement biological control should consider releasing *Goniozus legneri* on a yearly basis and continue to implement winter sanitation in addition to the parasitoid releases. There may be ways to collect infested mummies during the late summer and early fall and hold them under covered conditions in enclosed areas to enhance winter survival of the parasitoid.

The results of the scale monitoring indicated relatively low infestation in all but one of the test orchards. This was a BIOS orchard that averaged 707 male SJS per trap per season and only 564 *Encarsia perniciosi*. The use of pheromone traps can help almond growers track the abundance of male flyers. More importantly these same SJS pheromone traps can allow growers and pest control advisers to detect the presence of key scale parasitoids such as *Encarsia perniciosi* and *Aphytis* spp. By integrating the information gathered from SJS pheromone traps with visual symptoms on the trees, growers can move away from annual dormant sprays as a means of preventing SJS damage to trees. Also, the presence of parasitoids within orchards should give growers more confidence in managing scale with only horticultural oils during the dormant season, thereby eliminating the use of the more broad-spectrum sprays. Orchards using organophosphate sprays at hullsplit, in this study, averaged significantly fewer *Encarsia perniciosi* and numerically more SJS than growers not using these materials. It is clear that not all almond orchards in Merced and Stanislaus counties require annual dormant sprays to manage SJS and that the abundance of *Encarsia perniciosi* can be enhanced by not spraying with organophosphate or carbamate sprays.

From the Hendricks study (Hendricks, 1995), the question of a difference in relative abundance of pests in orchards could account for greater damage in the sprayed orchard compared to the unsprayed orchard. This is particularly true if there is found to be a major difference on infestation. Pest abundance was not measured in that study. Also, there is the possibility that the dynamics of the pest population could be influenced by sprays or beneficial arthropod activity, resulting in pests being active at different stages of nut susceptibility. The season long monitoring of both NOW and PTB in the orchards currently studied revealed no difference in the abundance of NOW eggs found or in the abundance of PTB males trapped. Even though neither trapping method is considered a good indicator of damaging populations, they are indicators of relative abundance and periods of sexual activity of both species. For instance, trapping of first male PTB indicates moths are present and timing of sprays are based on the greatest abundance of small worms. We were unable to detect any difference in the development of NOW or PTB flight initiation between the two management practices. Of particular interest was the lack of a difference in the numbers of PTB between the almond growers using the dormant and growing season sprays with those not using such sprays. Based on the pheromone trapping data, it can be assumed that the populations of both species of pests are equally present in both management practices.

NOW annually accounted for the greatest amount of nut damage, averaging 3.36 percent in the BIOS orchards and 2.35 percent in the Conventionally sprayed orchards. An average difference of one percent appears to be of minor importance when considering the cost of damage in relation to the expense of control. Even though the difference in NOW as not significant, the variation in infestation was usually greatest in the BIOS orchards. For example, BIOS grower 1 experienced 14 percent NOW infestation in 1996 and 6.2 percent NOW infestation in 1997. BIOS grower number 2 experienced 12.4% infestation in 1998. The greatest amount of NOW damage in the Conventionally sprayed comparison was 6.2, 9, and 8.2 percent in 1996, 1997, and 1998 respectively. This infestation was directly related to the number of mummies at harvest.

The damage from PTB was minimal in each of the years studied, never being greater than 1 percent. Although almond growers do consider damage from PTB as being an annual problem, during the period of this study it was not. If PTB infestation varies widely from year to year, being able to predict severity and having nondisruptive pesticides such as Bt and spinosad, almond growers could move away from the organophosphate, carbamate, and pyrethroid sprays used during the dormant season. Peach twig pheromones traps are currently used to predict timing of sprays (Rice, 1985). Four hundred to 500 degree-days after first moth flight in spring is the timing (using lower threshold of 52^o and an upper threshold of 88^o).

Ant damage was significantly less in the conventionally sprayed orchards. Although relatively low when compared to NOW infestation, individual BIOS growers did have economic damage (5.4 percent by BIOS grower 6 in 1996). Currently work is being done to evaluate thresholds for treating ants and also using selective baiting instead of broadcast spraying of organophosphates to control them. The use of flowering cover crops does enhance Southern fire ant, *Solenopsis xyloni* populations (Bentley, unpublished data).

Total insect damage was greatest in the BIOS orchards during 1996 averaging 7.13 percent while the Conventionally sprayed orchards averaged 3.89 percent in the same year. Total damage in 1997 averaged 2.96 and 2.84 percent for the BIOS and Conventionally sprayed orchards. Total damage in 1998 averaged 4.97 and 4.00 percent in the BIOS and Conventionally sprayed orchards. Although no significant difference in total damage was found between the two practices, many growers perceive that eliminating sprays will result in damage as experienced in 1996 from the unsprayed orchards.

The survey study conducted with another set of BIOS growers during 1996 and 1997 in Merced and Stanislaus counties verified the results of this study. One of the four comparisons resulted in significantly more damage than the county average (4.3 percent for Merced BIOS growers versus 2.5 percent for the county average in 1996). However, in all cases the BIOS growers did experience more damage than county average. Although the difference in damage may seem small to those of us not involved in producing the crop, many growers are not willing to risk higher damage.

Until reliable predictive techniques are found and reasonably effective nondisruptive control methods developed, many growers will not move away from using the more broad-spectrum insecticides. It is important for the almond industry to continue demonstrating to farmers and pest control advisers the success of new programs as they are being implemented.

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List of Publications Produced

Bentley, Walt, L. Hendricks, R. Duncan, C. Silvers, L. Martin, M. Gibbs, and M. Stevenson. 1999. A descriptive study of two approaches to insect pest management in almond orchards. California Agriculture. Submitted.

Bentley, W., C. Silvers, L. Hendricks, R. Duncan, and M. Gibbs 1998. Insect damage to almonds: A comparison between biologically integrated orchard systems (BIOS) and conventionally sprayed orchards (Abstr.). Entomological Society of America Annual Meeting, Portland, OR.

Bentley, W., C. Silvers, L. Hendricks, R. Duncan, and M. Gibbs. 1997. A comparison of BIOS and standard spray practices to manage pests of almond (Abstr.). Western Orchard Pest & Disease Management Conference, Portland, OR.

Bentley, W., C. Silvers, A.M. Ridgely, L. Hendricks, and R. Duncan. 1996. Specialized monitoring of almond BIOS orchards in Merced and Stanislaus counties. Report to the Almond Board of California.

APPENDICES

Figure 1. Average number of winter mummies per tree in six BIOS and six conventionally sprayed almond orchards.

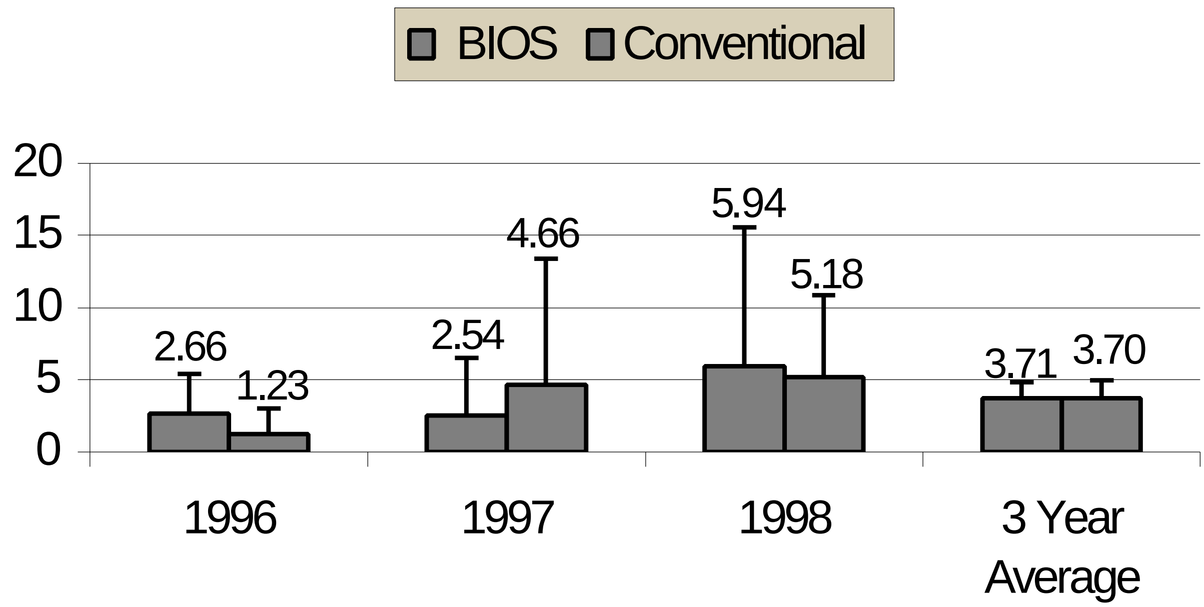

Figure 2. A three-year summary cv. Nonpareil infested with NOW based on winter mummy load.

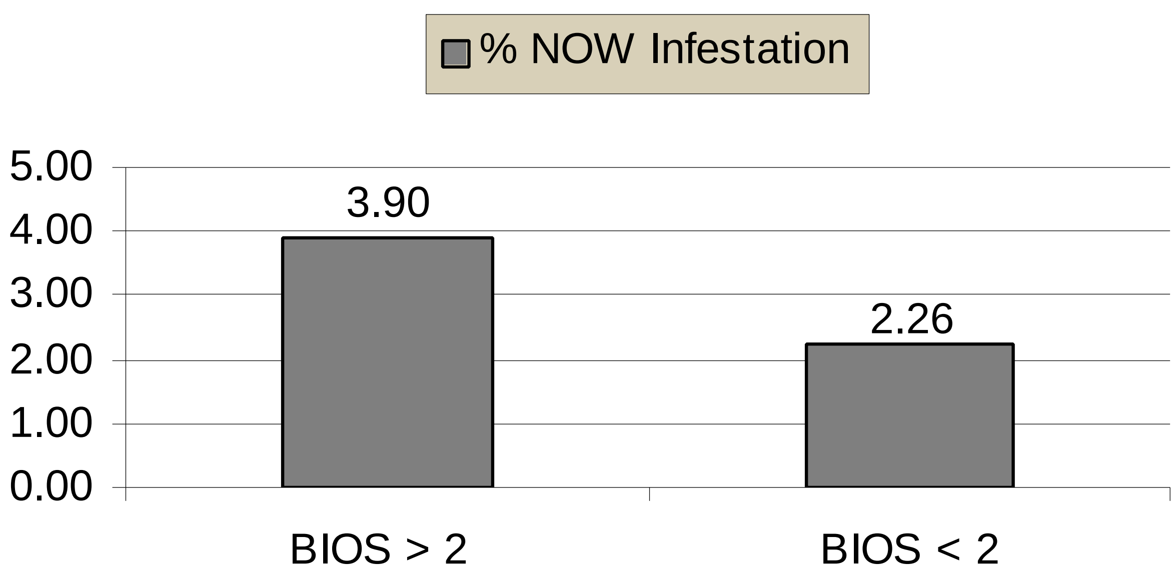

Figure 3. A three-year summary of abundance of San Jose scale, *Encarsia perniciosi*, and *Aphytis* spp. per tray per year in six BIOS and six conventionally sprayed almond orchards.

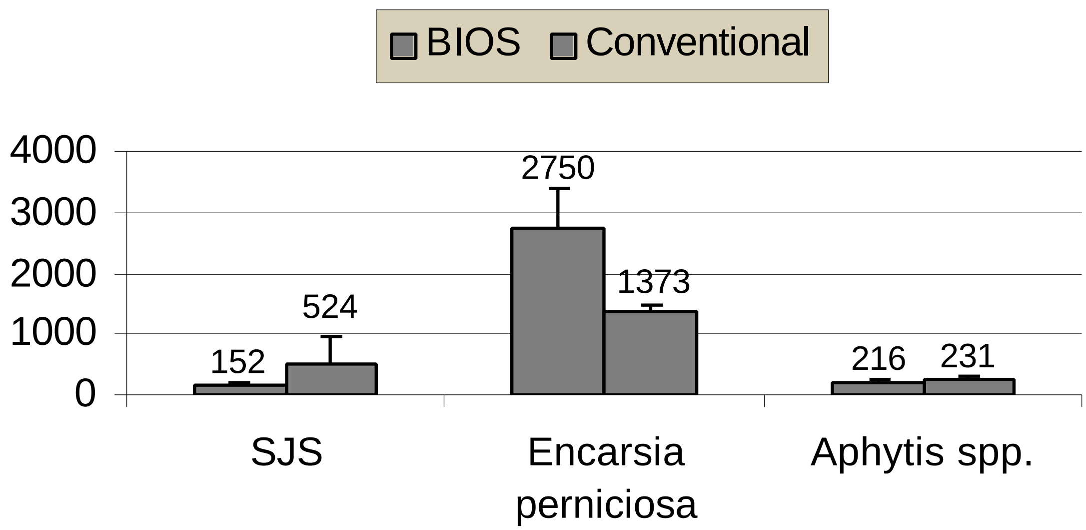

Figure 4. A three-year summary of total NOW eggs and PTB male moths per trap per year.

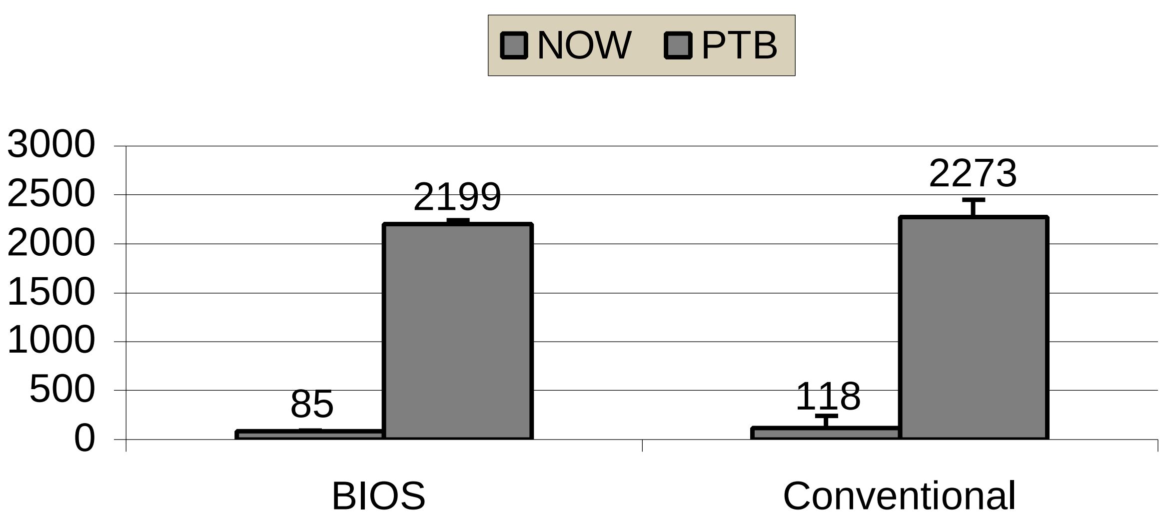

Figure 5. A three-year summary of insect infestation in six BIOS and six conventionally sprayed almond orchards.

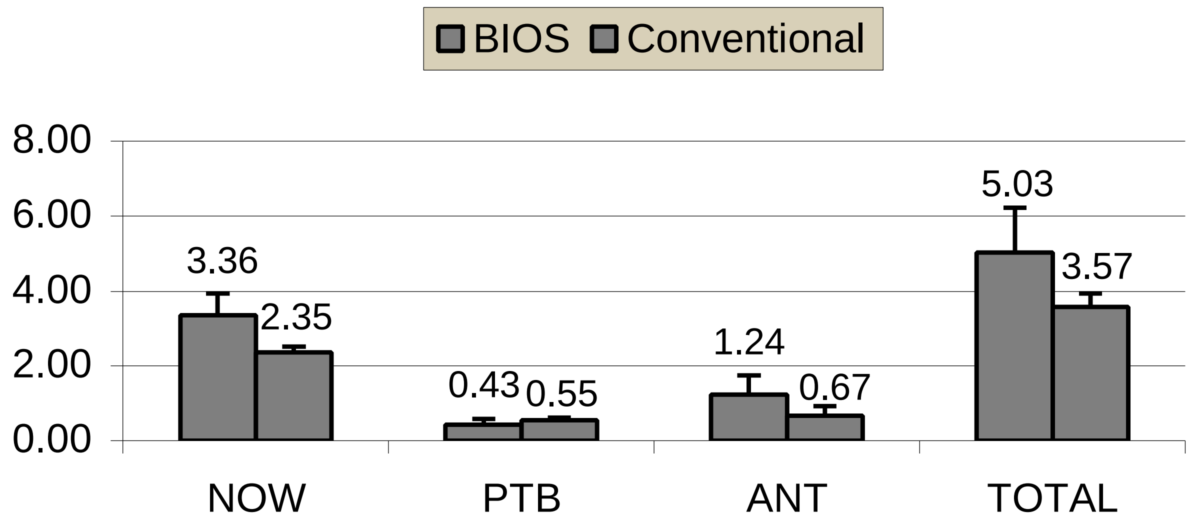

Table 1. Description of orchard comparisons.

Grower	Acreage	Cultivar	Age	Cover crop	Sanitation
BIOS 1	19 acres	66% NP : 33% Merced	23 years	Rich Mix, Low Grow Insectary every 10th row	no
Conventional 1	5 acres	66% NP, 33% Price	14 years	none	knocking, disking
BIOS 2	10 acres;	50% NP, 36% Price, 14% Neplus	10-11 years	Rich Mix with grains, cereals	no
Conventional 2	5 acres	50% NP, 36% Price, 14% Neplus	10-11 years	1/2 Rich Mix, with vetch	no
BIOS 3	8 acres	66% NP, 33% Merced	29 years	Low Grow	Poling
Conventional 3	20 acres	66% NP , 33% Merced	15+ years	none	Poling
BIOS 4	12 acres	50% NP, 50% Carmel	12 years	Low Grow	no
Conventional 4	25 acres	50% NP, 50% Carmel	12 years	resident vegetation, mowed	no
BIOS 5	20 (out of 91)	50% NP, 50% Carmel	17 years	Low Grow	yes
Conventional 5	20 (out of 83)	50%NP, 50%Price	17 years	Low Grow	yes
BIOS 6	40 acres	55% NP; Merced, Mission, Fritz, Price	35 years	self-seeded Rich Mix	yes
Conventional 6	20 acres	50% NP, 25% Neplus, 25% Mission	22 years	none	
BIOS 7	5 acres	50% NP; Mission Merced, Neplus	1972	Low Grow	no
Resident Vegetation 7	6 acres	50% NP; Price, Miss, Merced	1977	resident vegetation	no