CODLING MOTH CONTROL THROUGH MATING DISRUPTION


ABSTRACT:

Pheromonal control of codling moth (CM) is more dependent on the amount of pheromone in the orchard and not the distribution of the pheromone in the trees. False trail following does not appear to be the control mechanism. Both Consep and Shin-Etsu pheromone dispensers need to be placed high in the tree canopy to achieve their greatest effectiveness. Applications of pheromone dispensers can be made much more cost efficient through the development of a continuous line dispenser. The application of insecticides and pheromone dispensers combined can achieve greater control than either control tactic alone. CM control was achieved with 400 Consep dispensers per acre, but not 200 dispensers per acre.

OBJECTIVES:

The long-range objective of this project is to develop the CM pheromone mating disruption technique in walnuts. This year's objectives were to: 1) determine the mechanism of pheromone control, 2) reduce the cost through improvement in pheromone dispenser application technology, combination of insecticides and pheromone, and development of alternate pheromone dispenser products, and 3) provide Dr. Millar (UCR) CM larvae and/or pupae from different hosts and locations for analysis of pheromone gland constituents and volatiles produced by live virgin females.

PROCEDURES:

Mechanism of Pheromonal Control - A preliminary study on the control mechanism was conducted on 10 year old Ashley walnuts in Crows Landing, Calif. The trees were approximately 25-30 ft. tall and there were 48 trees per acre in an off-set planting. Four treatments were replicated four times in a randomized complete block design. Each replicate was a 5 tree block. The four treatments were: 400 full length codling moth dispensers (Shin-Etsu) per acre (8 per tree), 800-1/2 length codling moth dispensers per acre (16 per tree), 1600-1/4 length codling moth dispensers per acre (32 per tree) and an untreated control. The 1/2 and 1/4 length dispensers were made by cutting full length dispensers and sealing the cut ends. The dispensers were placed in the top of the tree canopy on April 8.

Codling moth was monitored by pheromone traps (Pherocon/1CP-Trece) using caps loaded with 1 mg Codlemone. One trap was placed high in the tree canopy in the center tree of each replicate on April 8 and monitored
weekly through July 6. The pheromone caps were changed once a month and trap bottoms were changed when necessary.

**Pheromone Dispenser Placement in the Tree** - A study was conducted to determine if Consep pheromone dispensers need to be placed high in the tree canopy to disrupt mating. This study was similar to the 1990 study on pheromone dispenser placement. In the 1990 study, Shin-Etsu dispensers were used for the placement study and there has been some question of whether the Consep pheromone dispensers also need to be placed high in the tree canopy. The study was conducted on 25 year old Payne walnuts in Crows Landing, Calif. The trees were approximately 40-45 ft. tall and there were 48 trees per acre in an off-set planting. Three treatments were replicated four times in a randomized complete block design. Each replicate was a 5 tree block. The four treatments were: four Consep dispensers placed high in the tree canopy (35 to 40 ft.), four Consep dispensers placed low in the tree canopy (6 to 10 ft.), and untreated control.

Codling Moth was monitored by pheromone traps (Pherocon/1CP-Trece) using caps loaded with 1 mg Codlemone. One trap was placed high in the tree canopy in the center tree of each replicate on April 8 and monitored weekly through July 7. The pheromone caps were changed once a month and trap bottoms were changed when necessary.

**Rapid Deployment of Pheromone Dispensers**. - A preliminary study was conducted to determine more cost efficient ways to apply the pheromone dispensers. Two rapid deployment techniques were investigated in Tulare, Calif. One technique was to construct a continuous line of twine with small loops tied approximately 1 ft. apart. The pheromone dispensers could be tied to the loops and the line pulled through the top of the tree canopy. The second technique was to use a continuous line of twine without the loops. This method was intended to mimic the development of a continuous line pheromone dispenser which was developed by Shin-Etsu for the control of diamondback moth and could be loaded with CM pheromone. The study was conducted in 25-30 ft. Ashley walnuts. A pruning tower with an outrigger to center the line on the top of the trees was used to deploy both types of continuous lines. The lines were placed in 1 row, which was about 1/4 mile long.

**Control of First Flight Codling Moth by the Combination of Insecticides and Pheromones** - A study was conducted on 8 year old Ashley walnuts in Tulare Calif. The trees were approximately 25-30 ft. tall and there were 48 trees per acre. Pheromone dispensers (Shin Etsu) were applied at a rate of 0, 100, 200, 400 and 800 dispensers per acre on March 19-20 to the top of the tree canopy. Each plot was 4.9 acres in size. The plots were divided in half and one half was treated with Lorsban at 4 pints/acre on April 20 while the other half remained untreated with insecticides. The study was terminated at the end of the first flight on June 1.
Codling moth was monitored by Pheromone traps and codling moth-infested dropped nuts. Three pheromone traps (Pherocon/1CP Trece) were placed in the center of each plot. Two of the traps were baited with 10 mg Codlemone and one trap was baited with 1 mg of Codlemone. Two traps (1 and 10 mg Codlemone) were placed high in the tree canopy (20-25 ft.) and the other trap (10mg Codlemone) was placed in the orchard on March 20 and monitored weekly through June 1. The pheromone caps were changed once a month and trap bottoms were changed when necessary. Codling moth-infested dropped nuts were monitored weekly from May 5 through June 1 from 10 trees in the center of each plot.

Development of Alternate Pheromone Dispenser Products - A study was conducted in a mature commercial Ashley walnut orchard near Marysville, CA. The trees were planted on a 40 ft. square, with one in the middle, and were approximately 35 to 40 ft. tall. Four treatments were established in this orchard. The treatments were: 1) 200 Consep CM pheromone dispensers/acre, 2) 400 Consep CM pheromone dispensers/acre, 3) grower standard (insecticide treated), and 4) untreated control. All pheromone dispensers were placed near the top of the tree canopy (approximately at 30 ft.) on March 17, May 13 and again on July 17. The pheromone and grower standard treatments were each 5.1 ac in size and the untreated control was 1.9 ac. The 200 pheromone dispenser treatment was reduced in size to 2.5 acre on June 11 because of a large number of CM-infested dropped nuts. Although, pheromone dispensers were placed over the 5.1 ac plot. The pheromone treatments were placed downwind from the grower standard and untreated control treatments. The grower standard was treated with Lorsban on May 1, Diazinon on May 25, Guthion on June 18, Diazinon on July 6 and Lorsban on August 5.

In each of the grower and standard and untreated control treatments, adult CM were monitored by placing 3 pheromone traps (Pherocon/1CP-Trece) baited with 1 mg of Codlemone at a height of approximately 30 ft. in the tree canopy. In each of the 200 and 400 pheromone dispenser treatments, adult CM were monitored by placing 2 pheromone traps (Pherocone /1CP-Trece), one baited with 1 mg of Codlemone and the other baited with 10 mg Codlemone at a height of 30 ft. in the tree canopy, and 1 trap baited with 10 mg of Codlemone at a height of 6 ft. in the tree canopy. The traps were placed in the Orchard on March 17 and monitored weekly through August 25. Pheromone caps were changed every 4 weeks and interior trees from each plot were collected weekly and bottoms were changed when necessary. All dropped nuts around 10 interior trees from each plot were collected weekly from May 13 through June 11 and inspected for CM infestation. Corrugated cardboard emergence bands were placed around the trunks of 10 interior trees in each treatment on May 12 and again on August 6. The bands were removed June 11 and August 27, respectively, and inspected for the presence of CM. At commercial harvest on August 28, 100 nuts/tree were collected from around 10 interior trees and inspected for CM and navel orangeworm NOW infestation.
Host Race and Regional Differences in Codling Moth Pheromone - CM larvae and pupae were collected from walnut in Tulare and Marysville and sent to Dr. Millar at UCR for analysis of the pheromone gland constituents and the volatiles produced by live virgin females.

RESULTS AND DISCUSSION:

Mechanism of Pheromonal Control - There was a significant reduction in mean number of moths/trap captured in the 400-full length dispensers/acre, 800-1/2 length dispensers/acre and 1600-1/4 length dispensers/acre treatments as compared to the untreated control, while there was no significant difference among the 400, 800 and 1600 dispensers/acre treatments (Table 1). The accumulated moth catch shows nearly identical numbers of moths captured until May 18 in the three dispenser treatments (Fig. 1). After May 18, the 800-1/2 length dispensers captured consistently lower number of moths.

Since the amount of pheromone was held constant between the three dispenser treatments while the length and number of pheromone dispensers varied between treatments, and since there was not a trend towards fewer moths captured with increasing number of pheromone dispensers, the data would suggest that the mechanism of pheromonal control is not solely based on false trail following. This study would also indicate that the number of pheromone dispensers placed in a tree is less critical than the amount of pheromone, and pheromone dispensers may be placed close together instead of spreading them around the tree. However, these results should be considered preliminary at this time because of the plot size and the inability to monitor female population using bait pan traps. It is hoped that next year a much larger plot can be established with variable length and number of pheromone dispensers.
Table 1. Mean number of codling moth per trap captured in trees treated with variable length pheromone dispensers.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mean* No. (± S.D.) of Moth/trap</th>
</tr>
</thead>
<tbody>
<tr>
<td>400-full length dispensers/ac</td>
<td>68.5 ± 17.0a</td>
</tr>
<tr>
<td>800-1/2 length dispensers/ac</td>
<td>43.0 ± 30.5a</td>
</tr>
<tr>
<td>1600-1/4 length dispensers/ac</td>
<td>75.3 ± 73.6a</td>
</tr>
<tr>
<td>Untreated Control</td>
<td>329.5 ± 55.1b</td>
</tr>
</tbody>
</table>

*Means followed by the same letter are not significantly different (Fisher's LSD, P ≤ 0.05). Trapping period was from April 8 through July 6, 1992.

Pheromone Dispenser Placement in the Tree - There was a significant reduction in mean number of moths/trap captured in the high and low pheromone placement treatments as compared to the untreated control, while there was no significant difference between the high and low placement treatments (Table 2). However, the high pheromone placement treatment consistently captured fewer moths than the low pheromone placement treatment (Fig 2). These results, using Conseps pheromone dispensers, were very similar to the 1990 results using Shin-Etsu pheromone dispensers (see 1990 Walnut Board Report). This year study and the 1990 study indicate that pheromone dispensers need to be placed high in the tree canopy to achieve their greatest effectiveness. Placement of the pheromone dispensers low in the tree canopy will suppress CM trap capture but not to the same degree as placing the pheromone dispensers high in the tree canopy. This is particularly important with large trees such as walnuts with a height of 30 to 40 ft., as compared to pears or apple with a tree height of 15 to 30 ft.

Table 2. Mean number of codling moth per trap captured in trees treated with pheromone dispensers placed high and low in the tree canopy.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean* No. (± S.D.) of Moth/trap</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Pheromone Placement</td>
<td>64.8 ± 12.2 a</td>
</tr>
<tr>
<td>Low Pheromone Placement</td>
<td>114.3 ± 28.5 a</td>
</tr>
<tr>
<td>Untreated Control</td>
<td>245.0 ± 54.3 b</td>
</tr>
</tbody>
</table>

*Means followed by the same letter are not significantly different (Fisher's LSD, P ≤ 0.05). Trapping period was from April 8 through July 6, 1992.

Rapid Deployment of Pheromone Dispensers - The application of the continuous line with or without loops, using a pruning tower was successful over the 1/4 mile row length. We speculate that a helicopter could be used to apply the line in very tall trees. Also, the reapplication of the continuous line without loops was successful. To reapply the line, we tied a new line onto the old line and pulled the old line out of the 1/4 mile
row. However, we were not successful in reapplying a new continuous line with loops. The loops became entangled with the tree and the line broke. The continuous line without loops successfully survived harvest and we will determine next spring if new line can be reapplied using the old line that overwintered in the trees.

If a continuous line of CM pheromone dispensers can be produced then the cost of application will be dramatically reduced. We estimate that one man on a pruning tower can apply approximately 100 acres of pheromone per day. Both Consep and Shin-Etsu are investigating the possibilities of developing a continuous line CM pheromone dispenser. If the products are made available next year, we will investigate their effectiveness in CM control.

Control of First Flight Codling Moth by the Combination of Insecticides and Pheromones - The application of pheromone dispensers or pheromone dispensers in combination with a spring application of Lorsban caused a reduction in the number of codling moth-infested dropped nuts (Fig. 3). In the untreated control (no pheromone or insecticide), the number of codling moth-infested dropped nuts was 22.5/tree. The number of codling moth-infested dropped nut was reduced to 9.0/tree when 100 dispensers were applied, and stabilized around this level with increasing amounts of pheromone dispensers. Even in the 800 dispensers per acre treatment, there were 8.3 codling moth-infested dropped nuts per tree. However, when Lorsban was applied in combination with pheromones, the number of codling moth-infested dropped nuts continued to decrease with increasing amounts of pheromone per acre. Thus there appears to be a synergistic effect with the insecticide and pheromone. This data would suggest that in orchards with a high population of codling moth in the spring, the combination of both insecticide and pheromone will be necessary to reduce the population to very low levels and the reliance on either control tactic alone will not suppress CM to these levels.

The pheromone traps baited with 10 mg of Codlemone and placed low in the tree canopy captured very few moths as compared to traps baited with either 1 or 10 mg of Codlemone placed high in the tree canopy. It was hoped that by increasing the amount of Codlemone in the traps, we would be able to monitor codling moth in pheromone treated orchards from traps placed low in the tree canopy. However, this does not seem to be possible. When pheromone traps were baited with 10 mg of Codlemone and placed high in the tree canopy, the traps in the 100 and 800 pheromone dispensers per acre treatments captured fewer moths than traps in the 200 pheromone dispenser treatment, which captured fewer moths than the 400 pheromone dispenser treatment (Fig. 4). It appears that the moths can locate the traps when background pheromone concentration is in the correct balance with the pheromone that is being emitted from the trap. If the background pheromone concentration is high, the moths can not locate the trap's pheromone plume, while if the background pheromone concentration is low, the moths can locate the trap's pheromone plume but will not enter the
trap because of high pheromone concentration surrounding the trap. When pheromone traps were baited with 1 mg of Codlemone and placed high in the tree canopy, the traps in the 800 pheromone dispensers per acre treatment captured fewer moths than the other treatments, which did not differ (Fig 5). It appears that the moths were able to locate the trap's pheromone plume in all treatments but the 800 dispensers per acre treatment and if they located the trap's pheromone plume then they would enter the trap. Also, it appears that in walnuts under high codling moth population pressure that the number of dispensers per acre needed to provide control would be greater than 800 dispensers per acre.

Development of Alternate Pheromone Dispenser Products - CM response, as measured by moth catch in pheromone traps baited with 1 mg or 10 mg of Codlemone and placed high in the tree canopy, was suppressed by both the 200 and 400 pheromone dispenser treatments but not completely eliminated (Table 3). In the 1 mg of Codlemone, totals of 21.7 and 12.0 moths/trap for the entire season were captured in the 200 and 400 pheromone dispenser treatments, respectively. In the 10 mg of Codlemone, totals of 8.3 and 11.0 moths/trap for the entire season were captured in the 200 and 400 pheromone dispenser treatments, respectively. In the 1 mg Codlemone, totals of 419 and 618 moths/trap for the entire season were captured in the grower standard and untreated control, respectively.

Table 3. Accumulated mean number of codling moth per trap captured for the entire season in the 200, 400 pheromone dispenser, grower and untreated plots.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mean No. (+ S.D.) of moth/trap</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High 1mg</td>
</tr>
<tr>
<td>200 dispensers/ac</td>
<td>21.7 ± 22.9</td>
</tr>
<tr>
<td>400 dispensers/ac</td>
<td>12.0 ± 3.7</td>
</tr>
<tr>
<td>Grower</td>
<td>419.0 ± 122.2</td>
</tr>
<tr>
<td>Untreated Control</td>
<td>618.7 ± 261.0</td>
</tr>
</tbody>
</table>

There was a significant reduction in the number of CM-infested dropped nuts in the 400 pheromone dispenser treatment and grower standard as compared to the untreated control and 200 pheromone dispenser treatment (Table 4). And the 200 pheromone dispenser treatment had significantly fewer dropped nuts than did the untreated control. Totals of 2.2 and 5.3 CM-infested dropped nuts per tree were found in the 400 and grower standard treatments, respectively, while a total of 10.6 and 15.9 infested dropped nuts per tree were found in the 200 pheromone dispenser and untreated control treatments. At this point in time, the 200 pheromone dispenser treatment was reduced in size from 5.1 acres to 2.5 acres. The plot was reduced to limited potential losses to the grower.
Table 4. Mean number of codling moth-infested dropped walnuts per tree.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mean* No. (+ S.D.) CM-infested walnuts/tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 dispensers/ac</td>
<td>10.6 ± 4.5b</td>
</tr>
<tr>
<td>400 dispensers/ac</td>
<td>2.2 ± 1.9a</td>
</tr>
<tr>
<td>Grower</td>
<td>5.3 ± 3.2a</td>
</tr>
<tr>
<td>Untreated Control</td>
<td>15.9 ± 3.8c</td>
</tr>
</tbody>
</table>

*Means followed by the same letter are not significantly different (Fisher's LSD, P ≤ 0.05).

The results from the first banding evaluation were similar to those from the dropped-nut evaluation (Table 5). However, the number of larvae or pupae were much lower and the 200 pheromone dispenser treatment was not significantly different from the other treatments. The moderate number of CM-infested dropped nuts and CM in the bands in the 200 pheromone dispenser and untreated control treatments and the high number of moth captured in the grower standard and untreated control indicated a moderate base level of CM in the orchard from the overwintering population. Based on the low number of CM-infested dropped nuts and the low number of larvae and/or pupae in the bands in the 400 dispenser treatment, a second application of pheromone dispensers were applied on July 17.

Table 5. Mean number of codling moth larvae and pupae in corrugated emergence bands per tree on two dates.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mean* No. (+ S.D.) CM/tree on:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6/11</td>
</tr>
<tr>
<td>200 dispensers/ac</td>
<td>0.5 ± 0.7ab</td>
</tr>
<tr>
<td>400 dispensers/ac</td>
<td>0.2 ± 0.4a</td>
</tr>
<tr>
<td>Grower</td>
<td>0.0 ± 0.0a</td>
</tr>
<tr>
<td>Untreated Control</td>
<td>0.9 ± 0.8b</td>
</tr>
<tr>
<td></td>
<td>8/27</td>
</tr>
<tr>
<td>200 dispensers/ac</td>
<td>1.9 ± 1.7b</td>
</tr>
<tr>
<td>400 dispensers/ac</td>
<td>0.7 ± 0.9ab</td>
</tr>
<tr>
<td>Grower</td>
<td>0.3 ± 0.5a</td>
</tr>
<tr>
<td>Untreated Control</td>
<td>4.0 ± 2.1c</td>
</tr>
</tbody>
</table>

*Means followed by the same letter are not significantly different (Fisher's LSD, P ≤ 0.05).

After the second pheromone application, the treatments were further evaluated by corrugated bands and nut infestation at harvest. The results from the second banding evaluation (Table 5) were similar to the final infestation at harvest (Table 6). However, the 200 pheromone dispenser showed fewer larvae and/or pupae in the bands than would be indicated by the percent infestation at harvest. At harvest, the portion of the 200 pheromone dispenser plot that was treated with insecticides after June 11 was also sampled by inspecting 100 nut from 10 trees. The results at harvest show that the grower standard, 200 pheromone dispensers plus insecticides, and 400 pheromone dispenser treatment had significantly
fewer CM than did the 200 pheromone dispenser or untreated control. Although the the grower standard and 400 pheromone dispenser treatment were not significantly different, the 400 pheromone dispenser treatment had approximately twice the infestation of the grower standard.

From this study, it appear that the Consep pheromone dispenser is a viable alternative to the Shin-Etsu dispenser with both products proving capable of providing acceptable control of CM. From this year's study, it appears that the minimum number of Consep dispensers to provide control is approximately 400 per acre while from last year's study, the minimum number of Shin-Etsu dispensers to provide control in approximately 800 per acre.

Table 6. Mean percent of codling moth- and navel orangeworm-infested walnuts per tree at commercial harvest.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean* No. (+ S.D.) infested walnuts/tree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CM</td>
</tr>
<tr>
<td>200 dispensers/ac</td>
<td>4.6 ± 1.7b</td>
</tr>
<tr>
<td>200 dispensers/ac +</td>
<td>0.9 ± 1.0a</td>
</tr>
<tr>
<td>insecticides</td>
<td>1.3 ± 0.6a</td>
</tr>
<tr>
<td>400 dispensers/ac</td>
<td>0.7 ± 0.8a</td>
</tr>
<tr>
<td>Grower</td>
<td>4.1 ± 2.2b</td>
</tr>
<tr>
<td>Untreated Control</td>
<td></td>
</tr>
</tbody>
</table>

*Means followed by the same letter are not significantly different (Fisher's LSD, P ≤ 0.05).

Note. This was an unreplicated study and replicates were obtained by using subsamples. Thus, results must be viewed as preliminary. Validation of these results will have to wait until replicated trials can be completed.

Host Race and Regional Differences in Codling Moth Pheromone - See J. Millar report for host race and regional differences in CM pheromone production.

ACKNOWLEDGMENTS:

We greatly acknowledge Mr. Ren Fairbanks of Deseret Farms and Mr. Chandler Wilcox of Visalia for their cooperation and willing assistance in various aspects of this study.
Fig. 1 Accumulated No. of Moths/Trap when Trees were Treated with Variable Length Pheromone Dispensers

Fig. 2 Accumulated No. of Moths/trap when Pheromone Dispensers were Placed High and Low in the Tree Canopy
Fig. 3 Effects of Variable Number of Pheromone Dispensers per Acre with and without an Insecticide Application on Nut Drop

![Graph showing mean number of CM-infested dropped nuts per tree versus number of dispensers per acre.](image)

**Legend:**
- Pheromone + Insecticide
- Pheromone

Fig. 4 Pheromone Traps Baited with 10 mg Codlemone Placed High in the Tree in Various Pheromone Density Plots

![Graph showing accumulated mean number of moths per trap over time for different dispensers per acre densities](image)

**Legend:**
- 100 Dispensers/Ac
- 200 Dispensers/Ac
- 400 Dispensers/Ac
- 800 Dispensers/Ac

**Dates:**
- 3/30
- 4/6
- 4/13
- 4/20
- 4/27
- 5/4
- 5/11
- 5/18
- 5/25
- 6/1
Fig. 5 Pheromone Traps Baited with 1 mg Codlemone Placed High in the Tree in Various Pheromone Density Plots

Accum. Mean No. of Moths/Trap


Date

100 Dispensers/Ac
200 Dispensers/Ac
400 Dispensers/Ac
800 Dispensers/Ac