DETERMINING IMPACT OF THIRD GENERATION, EMERGENCE PATTERN OF OVERWINTERED MOTHS, AND EFFICACY OF PHENOXYCARB ON CODLING MOTH

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ABSTRACT

Research conducted in 1988 and 1990 indicate that 50% or more of walnuts infested before June 30 drop from the tree and are not harvested. Later, the amount being harvested increases as harvest is approached. In 1989 data indicate overwintered larvae which receive the most chilling units emerged over a shorter period of time when compared to larvae exposed to less chilling units. This same pattern was not experienced in 1990 indicating other factors may be as important or more important than winter chilling. An insect growth regulator, phenoxy carb, was also tested to determine its impact on codling moth and beneficial organisms in walnuts.

OBJECTIVES

1. Determine when during the growing season codling moth infested nuts could survive the harvest process and be scored as offgrade.

2. Determine the factors important in the emergence of the overwintered generation of codling moth.

3. Determine the efficacy of phenoxy carb on codling moth and the impact on important beneficial species.

IMPACT OF THIRD BROOD CODLING MOTH

PROCEDURE

Experiments to determine the time of infestation that results in offgrade nuts were conducted in two mature Serr orchards in 1988 and one mature Serr orchard in 1990.

Nuts were first tagged on June 24, in 1988 and June 30, 1990. Walnuts showing signs of being recently infested with codling moth were tagged at weekly intervals in 1988 and biweekly in 1990. Each tagged nut was marked with different colored flagging tape so they could be found and identified at harvest. Up to 10 infested nuts from a minimum of 10 trees (100 nuts per week) were flagged each date. Tagged nuts were enclosed in mesh bags to catch nuts in case they dropped before harvest.

Nuts were harvested on September 6 in 1988 and September 15 in 1990. Husks were removed by hand, subsamples placed in separate mesh bags and dried in a commercial dryer. After drying, nuts were frozen for one week to kill live worms inside the nuts.

Nuts in the WSFS orchard were artificially infested by drilling a 3/16 inch hole in 10 nuts on 10 trees (100 nuts) and placing one 3rd instar laboratory reared codling moth in each nut. Holes were sealed with window putty to prevent larvae from leaving the nut.
Subsamples were combined into one composite sample for each date. Nuts were then run through an airleg and "blows" and good nuts collected in separate bags. The total number of remaining nuts, (blows and no blows) were then recorded. In addition individual nuts cracked, and a determination made as to whether they were damaged by codling moth only or CM and NOW.

RESULTS AND DISCUSSION

Although 100 nuts exhibiting sign of codling moth were tagged each week, with few exceptions, only about 50 percent of the nut meats were actually infested by codling moth, Table 1. The higher infestation rate observed on July 28 and Sept 6, 1988 cannot be explained except that the Sept. 6 was collected at harvest.

The percentage of infested nuts eliminated by the airleg declined as harvest approached. The most dramatic drop in the percent of infested nuts actually reaching the processor occurred about August 1. This corresponds to the time packing tissue color change started Table 1. Whether this was due to the time of infestation by codling moth or to the presence of NOW is unclear.

However the importance of the third brood cannot be ignored. Not only does the higher percentage of worms infest the meats but the percent of damaged nuts eliminated during the harvest operations is lower.

Although the percent of the infested nuts eliminated by the airleg at the WSFS in 1988 was somewhat higher than that experienced in the naturally infested orchards, the trends are the same with a lower percentage of infested nuts being eliminated as harvest was approached. One obvious reason is that practically 100 percent of the artificially infested nuts at the WSFS were infested with NOW. Another possible explanation for the higher percent of blows at the WSFS was the damage caused to the nut while drilling was more severe than the feeding damage of a high percentage of the naturally infested nuts where in many cases the damage caused by codling moth feeding was often very minor. This could have been caused by several reasons. One is that the larvae almost completed their development in the husk before entering the nut meat therefore feeding for only a short period of time before exiting the nut to pupate. Another reason could be that for some reason the survivability of larvae feeding in nut meats early in the season could be lower.

There was little doubt where feeding was extensive prior to packing tissue color change, infested nuts shriveled and did not survive to be delivered to the processors. However if damage is minor, nuts will, continue to develop after sustaining damage and survive the harvest process. They eventually end up in the grade and are classified as culls by the processor. This is especially true of anything infested after embryo development is complete. Another time during the nut development when the percentage of infested nuts surviving the harvest process increase dramatically is at the beginning of packing tissue color change.

DETERMINING CODLING MOTH EMERGENCE AFTER DIFFERENT AMOUNTS OF WINTER CHILLING

PROCEDURE

Corrugated cardboard bands were placed around the trunks or scaffolds of walnut trees to trap mature codling moth larvae as they crawled down the tree to spin overwintering cocoons. A minimum of 100 trees were banded in orchards located
near Tulare, on August 1, 1988 and near Hanford in 1989.

Cardboard bands containing overwintering larvae were collected at approximately monthly intervals throughout the winter and early spring. Initial collections were made on January 18 in 1989 and December 21 in 1989 for the 1990 season. Bands containing pre-pupae were brought into the laboratory and incubated at 70 degrees F. under natural light in 1989 and a 16:8 photophase in 1990. The amount of chilling was calculated as chill hours below 45 degrees F. beginning on November 1. Collection dates are listed in Figures 2 and 3. The last bands were collected when the first moth was collected in pheromone traps. The first moth was caught in pheromone traps on 3/18 in 1989 and 3/19 in 1990. Emerged adults were collected daily, sexed, and the number recorded to determine emergence rates.

RESULTS AND DISCUSSION

Many factors have been implicated as having an impact on the emergence of overwintered codling moth. Among those thought to be most important include the amount of winter chilling, time of diapause induction, photoperiod, and the accumulation of heat units in the spring.

Figure 4 shows the results of the impact of winter chilling on the emergence of overwintering codling moth in 1989. Moths left in the field the longest and receiving the most chilling generally emerged earlier until about 85 percent emergence was completed. When comparing those moths collected after 1062 chill units to those collected after 1414 chill units 50% emergence occurred almost 300 degree days earlier in those receiving the most chill units. However, the only double peak emergence occurred in those receiving the most chilling.

Emergence data from 1990 are not as clear cut. Initially the data indicate that the most rapid emergence occurred in the bands collected after 1419 chilling units. However, the second most rapid emergence occurred after 1007 chill units and bands receiving only 572 chilling units emerged at the same rate only 50 degree days later. The bands taking the most time to emerge received 1353 chill units which was the second most received. None of the treatments exhibited a bimodal emergence except the those receiving the maximum chilling. This same pattern was exhibited in 1989 and does not support the theory that winter chilling is as important as previously thought. It should be pointed out that the bands with the most chilling also receive the most heat units. Researchers in Germany indicate overwintering moths on the south side of trees receive more heat units in the spring than those on the north side, thus those on the south side emerge first causing the bimodal peak. This could also be important here.

At this time it is impossible to determine what is the cause of the bimodal emergence. It is probable that a number of factors are involved. Research is continuing on this problem and hopefully some time in the future overwintered emergence could be forecast which would allow growers to adjust their control program during those years when normal treatment timing does not fully cover the emergence.
EFFICACY OF PHENOXYCARB ON CODLING MOTH

PROCEDURE

This test was conducted in a 10 year old Serr walnut orchard located east of Easton, California. Materials tested included: fenoxycarb 25wp at 1 and 2 oz. AI/Acre, Guthion 50wp at 1.5 lb. AI/Acre, and an untreated check. Each treatment consisted of a single tree, replicated 4 times. The tree spacing is 45 X 22.5 feet in a diamond configuration (43 trees per acre). Trees were approximately 25 feet high. Treatments were applied on: 1. 4/18 when nut size averaged 12.2 mm in diameter, 2. June 18 one day after the beginning of the second flight and 3. August 14 at peak flight of the third flight, just before the beginning of husk split. Treatments were applied by handgun at 350 PSI with an average of 9.5 gallons being applied per tree (approximately 400 gallons per acre).

First generation codling moth control was evaluated by counting the number of dropped nuts under each tree. Second generation damage was evaluated by examining 200 nuts selected at random on each tree (800 nuts per treatment). Two hundred nuts were collected at random from the ground after trees were shaken for harvest. The harvest sample was cracked and evaluated for both codling moth and navel orangeworm.

Treatments were evaluated for the Pacific mite, *Tetranychus pacificus*, the predaceous mite *Metaseiulus occidentalis*, and insect predators, sixspotted thrips, *Scolothrips sexmaculatus* and spider mite destroyers, *Stethorus picipes* at regular intervals after mites started appearing in the plot. Samples consisted of picking 15 leaflets at random from each tree. Leaves were refrigerated immediately and transported to the laboratory for counting. Leaves were brushed with a standard mite brushing machine onto a glass plate and 25% of the plates were examined for the presence of motile stages under a binocular microscope.

Aphids were evaluated by selecting 10 mature leaflets at random from each tree and counting the number of aphids and aphid mummies present on each leaflet.

RESULTS AND DISCUSSION

Codling moth did not develop a high population in this orchard this year. This is difficult to explain since codling moth pheromone trap counts indicated a population well above that which would cause heavy damage.

Fenoxycarb at 1 and 2 oz. AI/Acre were significantly better than the check and were equal to control obtained with Guthion at 1.5 lb. AI/Acre, the standard material now used in California, at each sampling period, Table 2. When the total number of infested nuts for the season are compared the separation between treatments and the check is even more pronounced. Although not statistically significant there is an indication that the 2 oz. rate of fenoxycarb is superior to the 1 oz. rate. However, even the low rate was almost equal to the Guthion treatment.

This is more evident when one examines total worm damage in the harvest sample. At harvest, codling moth and total worm damage was significantly lower than the check in all treatments, Table 3. Although not significantly different there was a 40 and 60 percent reduction in navel orangeworm damage in the fenoxycarb
treatments compared to no reduction with Guthion. This indicates fenoxycarb may be more active against navel orangeworm than Guthion and warrants further investigation.

The Pacific mite populations began to increase in the Guthion treatment in late June and was significantly higher than the check and fenoxycarb treatments on June 30, Table 4. Numbers continued to increase in the Guthion treatment during July and were significantly different from the other treatments from August 1 until we stopped sampling at harvest on September 5. Severe defoliation was experienced on the trees treated with Guthion and if the entire orchard had been infested harvest would have been difficult. Although no data are presented, predaceous mites were present in very low numbers in the check and fenoxycarb treatments throughout the course of the experiment but sample size was not sufficient to detect significant differences. This indicates fenoxycarb is not disruptive to the biological control of mites and should fit well into a walnut IPM program.

Aphids did not build up in any treatments in this plot, Table 5. I cannot explain why we did not have an outbreak in the Guthion plots except perhaps T. pallidus has developed some resistance to this material.

Fenoxycarb appears to be a superior candidate as a selective codling moth material in walnuts. In addition to controlling codling moth there appears to be some activity on navel orangeworm. Selectivity appears to be excellent for both mite and aphid natural enemies.
Table 1. Harvest fate of Serr walnuts exhibiting codling moth damage at various times during growing season.

<table>
<thead>
<tr>
<th>Date</th>
<th>% Infested$^x$</th>
<th>1988</th>
<th>1990</th>
<th>% Infested$^1$ nuts Eliminated by Airleg</th>
<th>Tulare 1988</th>
<th>WSFS 1990</th>
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<tbody>
<tr>
<td>6/24</td>
<td></td>
<td>55</td>
<td></td>
<td></td>
<td>65</td>
<td>94</td>
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<td>6/30</td>
<td></td>
<td>56</td>
<td>26</td>
<td></td>
<td>77</td>
<td>89</td>
</tr>
<tr>
<td>7/7</td>
<td></td>
<td>40</td>
<td></td>
<td></td>
<td>40</td>
<td>95</td>
</tr>
<tr>
<td>7/14</td>
<td></td>
<td>49</td>
<td>33</td>
<td></td>
<td>47</td>
<td>68</td>
</tr>
<tr>
<td>7/21</td>
<td></td>
<td>52</td>
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<td></td>
<td>36</td>
<td>61</td>
</tr>
<tr>
<td>7/28</td>
<td></td>
<td>72</td>
<td>46</td>
<td></td>
<td>18</td>
<td>39</td>
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<tr>
<td>8/4</td>
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<td>45</td>
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<td>25</td>
<td>20</td>
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<td>58</td>
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<td>21</td>
<td>10</td>
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<td></td>
<td>13</td>
<td>4</td>
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<tr>
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<td>45</td>
<td>45</td>
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<td>25</td>
<td>3</td>
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<td>9/2</td>
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<tr>
<td>9/6</td>
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<td>68</td>
<td>43</td>
<td></td>
<td>4</td>
<td>19</td>
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<td>9/15 (Check)</td>
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<td>1</td>
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<td></td>
<td>10</td>
<td>1</td>
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</table>

$^1$ Infested = Insect feeding on nut meat.

$^x$ Percent of nuts exhibiting meat damage showing exterior signs of recent infestation with codling moth on dates indicated.

$^* $ 100 nuts drilled and artificially infested with third instar codling moth larvae.
Fig. 1

EMERGENCE OF OVERWINTERED CODLING MOTH
1989

Date Collected (Chill Units)

1/18 (911)
2/1 (1062)
2/27 (1333)
3/18 (1414)

% Emergence

0 20 40 60 80 100 120

Degree Days

0 200 400 600 800 1000 1200 1400
EMERGENCE OF OVERWINTERED CODLING MOTH
1990

% Emergence

Date Collected (Chill Units)
- 12/21 (572)
- 1/22 (1007)
- 2/21 (1353)
- 3/19 (1419)

Degree Days
Table 2.

Walnut Codling Moth Trial
Fresno County California
1990
W.W. Barnett and Catherine Pinto
UC Kearney Agricultural Center - Parlier, California

Codling Moth

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1st generation</th>
<th></th>
<th>2nd generation*</th>
<th></th>
<th>Harvest*</th>
<th></th>
<th>Seasonal Total</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Total Number</td>
<td>Dropped Nuts (4 trees)</td>
<td>Infested Nuts/800</td>
<td>Infested Nuts/800</td>
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</tr>
<tr>
<td>Check</td>
<td>15 a&lt;sup&gt;1&lt;/sup&gt;</td>
<td>20 a</td>
<td>21 a</td>
<td>56 a</td>
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<tr>
<td>Fenoxycarb</td>
<td>3 b</td>
<td>2 b</td>
<td>1 b</td>
<td>6 b</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1 oz AI/A</td>
<td>2 b</td>
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<td>0 b</td>
<td>2 b</td>
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<tr>
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<td>0 b</td>
<td>3 b</td>
<td>4 b</td>
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<td></td>
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</tr>
</tbody>
</table>

<sup>1</sup> Means followed by same letter are not different <P=.05> DMRT/

* 200 nuts collected from each single tree replicate.
Table 3.

Walnut Codling Moth Trial
Fresno County, California
1990
W.W. Barnett and Catherine Pinto
UC Kearney Agricultural Center, Parlier, California

Infested Walnuts Per 800 Nut Harvest Sample *

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Codling Moth</th>
<th>Navel Orangeworm</th>
<th>Total Worm Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td>21 a&lt;sup&gt;1&lt;/sup&gt;</td>
<td>9 a</td>
<td>30 a</td>
</tr>
<tr>
<td>Fenoxycarb 1 oz. AI/A</td>
<td>1 b</td>
<td>4 a</td>
<td>5 b</td>
</tr>
<tr>
<td>Fenoxycarb 2 oz. AI/A</td>
<td>0 b</td>
<td>6 a</td>
<td>6 b</td>
</tr>
<tr>
<td>Guthion 50W 1.5 #AI/A</td>
<td>3 b</td>
<td>10 a</td>
<td>13 b</td>
</tr>
</tbody>
</table>

<sup>1</sup> Means followed by same letter are not different <i>P=.05</i> DMRT.

* 200 Nuts collected from each single tree replicate.
Table 4.

Walnut Codling Moth Trial
Fresno County, California
1990
W.W. Barnett and Catherine Pinto
UC Kearney Agricultural Center, Parlier, California

<table>
<thead>
<tr>
<th>Treatment</th>
<th>6/30</th>
<th>7/10</th>
<th>7/18</th>
<th>7/27</th>
<th>8/1</th>
<th>8/9</th>
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<tbody>
<tr>
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<td>.07ns</td>
<td>.19ns</td>
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<td>.59 a</td>
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<td>.13</td>
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<td>4.7 b</td>
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<td>9.8 b</td>
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1: Means followed by same letter are not different (P=0.5) DMRT.
Table 5.

Walnut Codling Moth Trial
Fresno County, California
1990
W.W. Barnett and Catherine Pinto
UC Kearney Agricultural Center, Parlier, California

Walnut Aphids Per leaflet

<table>
<thead>
<tr>
<th></th>
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<tr>
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<td>1.7</td>
<td>.8</td>
<td>.4</td>
<td>1.3</td>
<td>.3</td>
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<td>Fenoxycarab 2 oz. Al/A</td>
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<td>2.3</td>
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