INVESTIGATIONS ON NAVAL ORANGEWORM CONTROL IN WALNUTS


ABSTRACT

Navel orangeworm populations were monitored using a modified NOW egg trap. The traps were painted black and baited with ground almond press cake plus 10% crude almond oil. It appears from the last two years' work that NOW can be effectively monitored with the egg trap. The nut infestation level correlates reasonably well with the mean number of eggs per trap per day from the beginning of the season to husk-split or harvest and the number of days from split to harvest. The equations for both years of study combined are:

Infestation level = -2.56 + 1.07 \(X\) E/T/D beginning to harvest + .17 (days from split to harvest), with a correlation coefficient of .63 and F value of 11.0

Infestation level = -2.56 + 1.03 \(X\) E/T/D beginning to split + 1.7 (days from split to harvest), with a correlation coefficient of .61 and F value of 10.3.

These equations should be used only as guidelines for the proper control strategy and are not meant to be definitive treatment levels. For example, an orchard that has had a low mean E/T/D for the season but experiences a great deal of moth activity at husk-split would warrant a rapid harvest or a husk-split treatment. Thus, this technique for monitoring NOW and determining the proper control strategy will require a great deal of experience and interpretation for it to work effectively.

When a number of insecticides were applied at husk-split for NOW control, Supracide, Guthion and FMC 54800 (not registered) gave good control (90%-80%). Zolone gave adequate control (70%) and Sevin provided the least effective control (40%). However, since the insecticides were applied only two weeks before harvest, the amount of control would be expected to be much less if harvest had been delayed one or two additional weeks.

OBJECTIVES

To develop a husk-split treatment scheme for navel orangeworm (NOW) control based on NOW egg traps and to evaluate insecticides for navel orangeworm control.

PROCEDURES

Population monitoring. A number of walnut orchards were monitored for codling moth and NOW in Tulare/Kings, San Joaquin/Stanislaus and Sutter/Butte counties in 1984. Codling moth was monitored by placing 4 Pherocon 1C traps in each orchard in late March or early April and inspecting the traps twice a week until harvest.
The pheromone was changed twice a month and the bottoms of the traps were changed when necessary. NOW was monitored by placing 8 NOW egg traps in each orchard in early April and inspecting the traps twice a week until harvest. The NOW egg traps were painted black and were baited with ground almond press cake plus 10% crude almond oil. The bait was changed once a month. Both codling moth and NOW traps were placed in a uniform manner in each orchard. At grower harvest, 250 nuts around each codling moth trap (1000 nuts per orchard) were inspected for codling moth and NOW damage.

Insecticide Evaluation. At the Westside Field Station, 5 treatments and an untreated control were replicated 8 times in a randomized complete block design. The treatments were Guthion 50% WP at 2.0 lb Ai/Ac, FMC 54800 2.0 EC and 0.08 lb Ai/Ac, Sevin 80 S at 5.0 lb Ai/Ac, Zolone 3 EC at 3.0 lb Ai/Ac, Supracide 2 EC at 2.0 lb Ai/Ac and an untreated control. Each replicate was an individual tree (Serr variety). The treatments were applied at husk-split (Sept. 5) with a hand-held orchard sprayer operating at 270 PSI. All materials were applied at 600 gal water/Ac. At harvest (Sept. 19), 100 nuts per replicate (800 nuts per treatment) were inspected for codling moth and NOW larvae and damage.

RESULTS AND DISCUSSION

Population Monitoring. The navel orangeworm population and number of days from husk-split to harvest varied considerably among and within the three growing areas (Table 1). In general, the Tulare/Kings area had the highest NOW populations but the fewest days from husk-split to harvest, while in both Sutter/Butte and San Joaquin/Stanislaus there was considerable variation among the orchards. In Tulare/Kings the mean number of days from husk-split to harvest was 15.4 ± 3.5 days, the NOW population was 2.4 ± 0.9 E/T/D (beginning to harvest), and the NOW infestation was 1.5 ± 1.2%. In Sutter/Butte the mean number of days from husk-split to harvest was 17.9 ± 5.8 days, the NOW population was 0.9 ± 0.8 E/T/D, and the NOW infestation was 3.0 ± 2.7%. In San Joaquin/Stanislaus the mean number of days from husk-split to harvest was 30.6 ± 10.2, the NOW population was 1.2 ± 1.3 E/T/D, and NOW infestation was 3.4 ± 3.8% (Table 1).

The Tulare/Kings orchards had considerable NOW activity throughout the season, with the exception of orchard 1 which showed very little activity until late July (Figs. 1-10). NOW trapping in the Tulare/Kings orchards was terminated before the final harvest due to miscommunication. However, in these orchards it was observed that despite very large NOW populations late in the season, NOW infestations can be controlled to acceptable levels by harvesting the walnuts within 2 weeks of husk-split. For example, in orchard 8 the NOW population was 3.15 E/T/D. The grower harvested 15 days after husk-split began, and the NOW infestation was only 1.0%. In contrast, in orchard 5 the NOW population was only 0.7 E/T/D. The grower harvested 22 days after husk-split began, and the NOW infestation was 2.7%. This reinforces the idea that early harvest is the most effective means of controlling NOW infestation.

The Sutter/Butte orchards varied considerably with respect to NOW population, days from husk-split to harvest, and final NOW infesta-
tion (Table 1 and Figs. 11-21). For example, orchards 6 and 7 (Figs. 16 & 17) had very low NOW populations, while orchards 8 and 9 (Figs. 18 & 19) had very high populations. Orchard 4 (Fig. 14) is a good example of how using seasonal mean E/T/D can result in erroneous assessment of the final NOW infestation level. In orchard 4 the seasonal mean was only 1.5 E/T/D. The grower harvested 19 days after husk-split began, and the final NOW infestation was 4.0%. However, the NOW population was very high late in the season from mid-August to harvest, and at harvest there were 25.3 E/T/D. Thus, each orchard will need to be assessed individually to determine the proper control strategy and simply relying on the seasonal E/T/D and number of days from split to harvest to determine final infestation levels can result in serious errors. In general, the higher the NOW population between husk-split and harvest, and the longer the time period between husk-split and harvest, the greater the NOW infestation level will be. The time-period between husk-split and harvest was also quite variable in the Sutter/Butte orchards. Orchard 6 was harvested 11 days after husk-split, while orchard 9 was harvested 32 days after husk-split.

The San Joaquin/Stanislaus orchards varied tremendously in both NOW population (0.19 to 6.88 E/T/D) and days from husk-split to harvest (9 to 45 days) (Table 1 and Figs. 22-29). The percent infestation was also quite variable, ranging from 0.3 to 11.0%. Again, based on the San Joaquin/Stanislaus orchards with a prolonged period between husk-split and harvest, a low NOW population can result in high NOW infestation levels. For example, orchards 7 and 8 which had 45 and 41 days from split to harvest and low NOW populations of 0.80 and 0.19 E/T/D, respectively, had infestation levels of 2.5 and 3.4%.

When the percent infestation from the 1983 and 1984 data was regressed against seasonal mean E/T/D from beginning of trapping to harvest or from beginning of trapping to husk-split and against the number of days from husk-split to harvest, a significant relationship at the 1% level was found (Table 2). Only orchards which did not receive a husk-split insecticide application for NOW were used in these regressions. The correlation coefficient for the 1983 regression was remarkably high at 0.82, considering the number of people collecting the data and the size of the project. These high correlations may have resulted from the limited number of orchards examined. The correlation coefficients of 0.66 and 0.64 for the 1984 regressions and of 0.63 and 0.61 for the combined 1983 and 1984 regressions were much lower and more reasonable. The regression equation can be constructed from Table 2. For example, the equation for 1983 and 1984 combined using beginning of trapping to harvest is:

\[
\% \text{ NOW infestation} = -2.56 + 1.07 \times (\text{E/T/D from beginning to harvest}) + 0.17 \times (\text{days from split to harvest}).
\]

Thus, an orchard with a season mean E/T/D of 2.0 and 20 days from husk-split to harvest would have a final infestation of 3.0%:

\[
3.0 = -2.56 + 1.07(2.0) + 0.17(20)
\]

However, it can not be overstressed that these equations are simply
guidelines and each orchard will need to be assessed individually to determine the proper strategy for NOW control. The control strategy can be early harvest with the use of Ethrel or a husk-split treatment or combination of both.

Insecticide Evaluation. All insecticides tested gave some degree of control of NOW and all were significantly more effective than the untreated control (Table 3). The codling moth population did not develop in this orchard and thus could not be evaluated. Supracide provided the best control, with only 0.38% of the nuts damaged. However, this degree of control might be somewhat misleading. Since the time period between application and harvest was only 14 days and since Supracide has about a 14-day residual period, the control might not have been as good had the time period been extended. Supracide currently is registered on walnuts with a 7-day preharvest interval. PMC 54800, which also provided excellent control, is a new pyrethroid product with some miticidal activity. The material is not registered on walnuts, but hopefully will become available within a few years. Guthion also provided excellent control and is the material of choice when NOW populations are high and a lengthy time period between split and harvest is anticipated. Guthion has a long residue period and is currently registered for use on walnuts. Guthion must be applied before husk-split. The problem with Guthion is its adverse effect on beneficial insects and mites. Walnut aphid and spider mites might become a problem after its use. Zolone provided reasonable control. However, it has a short residue period and, again, had the time period between application and harvest been prolonged, control might not have been as good. Zolone currently is registered on walnuts and it must be applied before husk-split. Sevin provided the poorest control of the materials tested. Because of Sevin's ability to cause flare-ups of spider mites, it is not recommended for NOW control.

CONCLUSIONS

Population Monitoring. It appears from our two years of study that NOW populations can be effectively monitored with the modified NOW egg trap and that NOW control strategy can be based on egg trap counts and anticipated days from husk-split to harvest. This control strategy is based on early harvest, husk-split treatment, or a combination of both. It is impossible to establish a fixed treatment level for NOW based solely on egg trap counts. The number of days from husk-split to harvest must also be considered since the longer the interval between husk-split and harvest, the longer the susceptible nuts are exposed to NOW.

Simple multivariate regressions have been constructed which can be used as simple guidelines. However, each orchard will need to be assessed individually to determine the proper control strategy. In general, any orchard with a high NOW population (greater than \(3.0 \times E/T/D\)) should be harvested within 2 weeks after husk-split and a husk-split treatment should be considered. Any orchard that is experiencing a build-up of NOW just before or after husk-split should be harvested as soon as possible and a husk-split treatment should be considered. Any orchard with an anticipated harvest of 30 or more days after husk-split should consider treatment (Supracide) when activity begins.
Insecticide Evaluation. Based on the last two years' studies, it appears that a number of insecticides can provide reasonable control of NOW. Guthion should be considered when the NOW population is high and the harvest is expected to be delayed. Zolone should be considered when the NOW population is moderate and the harvest will not be delayed. Supracide should be considered when the NOW population is high and husk-split has already occurred.

ACKNOWLEDGMENTS

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### Table 1

<table>
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<tr>
<th>Field No.</th>
<th>Variety</th>
<th>Husk-split spray</th>
<th>Days from husk-split to harvest</th>
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<th>Avg. % NOW Damage</th>
<th>Avg. % CM Damage</th>
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</table>

*Mean and (standard deviation) of orchards or portions of orchards which did not receive an insecticide application.
Table 2

Multiple Linear Regression Analysis of the Relationship between Percent Navel Orangeworm Infestation, Mean No. of Eggs/Trap/Day from the beginning of Trapping to Harvest or to Husk-Split, and No. of Days from Husk-Split to Harvest

<table>
<thead>
<tr>
<th>No. of orchards</th>
<th>Intercept</th>
<th>$X_{E/T/D}$ from beginning to harvest</th>
<th>$X_{E/T/D}$ from beginning to split</th>
<th>Days from split to harvest</th>
<th>Correl. Coeff.</th>
<th>F* value</th>
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<tr>
<td>13</td>
<td>-3.38</td>
<td>6.72</td>
<td>-</td>
<td>.12</td>
<td>.82</td>
<td>10.3</td>
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<td>-2.49</td>
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<td>-</td>
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<td>.66</td>
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<tr>
<td>36</td>
<td>-2.56</td>
<td>-</td>
<td>1.03</td>
<td>.17</td>
<td>.61</td>
<td>10.3</td>
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*All F values were significant at the 1% level.
### Table 3
Control of Navel Orangeworm and Codling Moth with Various Insecticides at WSFS, 1984

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<tr>
<th>Treatment</th>
<th>Navel orangeworm</th>
<th>Codling moth</th>
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<tbody>
<tr>
<td></td>
<td>Larvae present</td>
<td>Larvae not present</td>
</tr>
<tr>
<td>Supracide</td>
<td>0.25 a</td>
<td>0.13 a</td>
</tr>
<tr>
<td>FMC 54800</td>
<td>0.50 ab</td>
<td>0.13 a</td>
</tr>
<tr>
<td>Guthion</td>
<td>0.88 ab</td>
<td>0.13 a</td>
</tr>
<tr>
<td>Zolone</td>
<td>1.13 ab</td>
<td>0.38 a</td>
</tr>
<tr>
<td>Sevin</td>
<td>1.88 b</td>
<td>0.63 ab</td>
</tr>
<tr>
<td>Control</td>
<td>3.25 c</td>
<td>1.25 b</td>
</tr>
</tbody>
</table>

*Means followed by the same letter in a vertical column are not significantly different at the 5% level (DMRT)*.
Seasonal Activity of Navel Orangeworm and Codling Moth in Walnuts, Orchard 1, Tulare, 1984.

- NOW 1.1%
- CM 0.2%

Seasonal Activity of Navel Orangeworm and Codling Moth in Walnuts, Orchard 2, Tulare, 1984.

- NOW 2.4%
- CM 0.9%
Fig. 3  

Fig. 4  
Fig. 5

Seasonal Activity of Navel Orangeworm and Codling Moth in Walnuts, Orchard 5, Tulare, 1984.

- NOW 2.7%
- CM 0.0%

Fig. 6

Seasonal Activity of Navel Orangeworm and Codling Moth in Walnuts, Orchard 6, Tulare, 1984.

- NOW 0.3%
- CM 0.2%
Seasonal Activity of Navel Orangeworm and Codling Moth in Walnuts, Orchard 7, Tulare, 1984.

Seasonal Activity of Navel Orangeworm and Codling Moth in Walnuts, Orchard 8, Tulare, 1984.
Fig. 9
Seasonal Activity of Navel Orangeworm and Codling Moth in Walnuts, Orchard 9, Tulare, 1984.

- NOW 3.3%
- CM 0.1%

Mean No. Eggs/Traps/Night

April May June July August

Fig. 10
Seasonal Activity of Navel Orangeworm and Codling Moth in Walnuts, Orchard 10, Tulare, 1984.

- NOW 2.7%
- CM 0.0%

Mean No. Eggs/Traps/Night

April May June July August

Walnut Research Reports 1984
Seasonal Activity of Navel Orangeworm and Codling Moth in Walnuts, Orchard 1, Butte, 1984.

Mean No. Eggs or Moths/Trap/Night

- NOW 6.6%
- CM 8.5%


Mean No. Eggs or Moths/Trap/Night

- NOW 0.5% 0.7%
- CM 1.0% 0.0%
Fig. 13


- NOW 0.7%
- CM 0.0%

Fig. 14


- NOW 4.0%
- CM 0.0%
Fig. 15


Mean No. Eggs/Moths/Trap/Night

- NOW 2.3%
- CM 0.0%

Fig. 16


Mean No. Eggs/Moths/Trap/Night

- NOW 0.1%
- CM 1.6%
Fig. 17


Fig. 18

Seasonal Activity of Navel Orangeworm and Codling Moth in Walnuts, Orchard 8, Butte, 1984.
Fig. 19

Seasonal Activity of Navel Orangeworm and Codling Moth in Walnuts, Orchard 9, Butte, 1984.

[Graph showing seasonal activity with treated and untreated data for NOW (3.1% vs. 2.0%) and CM (1.1% vs. 1.7%).]

Fig. 20


[Graph showing seasonal activity with treated and untreated data for NOW (0.0% vs. 1.0%) and CM (0.0% vs. 0.0%).]
Fig. 21

Fig. 22
Seasonal Activity of Navel Orangeworm and Codling Moth in Walnuts, Orchard 1, San Joaquin, 1984.
Fig. 23


Fig. 25


- NOW 0.8%
- CM 0.7%

Mean No. Eggs or Moths/Trap/Night

April May June July August September

Fig. 26


- NOW 0.8%
- CM 1.2%

Mean No. Eggs or Moths/Trap/Night

April May June July August September
Fig. 27

Seasonal Activity of Navel Orangeworm and Codling Moth in Walnuts, Orchard 6, San Joaquin, 1984.

- NOW 5.2%
- CM 2.8%

Mean No. Eggs or Moths/Treat/night

April May June July August September

Fig. 28


- NOW 2.5%
- CM 0.6%

Mean No. Eggs or Moths/Treat/night

April May June July August September
Fig. 29

Seasonal Activity of Navel Orangeworm and Codling Moth in Walnuts, Orchard 8, San Joaquin, 1984.

- NOW 3.4%
- CM 0.4%

Mean No. Eggs or Moths/Trap/Night

April May June July August September