EFFECT OF ORCHARD FLOOR MANAGEMENT STRATEGIES ON SURVIVAL OF OVERWINTERED NAVEL ORANGEWORM IN 'MUMMY' WALNUTS

G. Steven Sibbett, R. Van Steenwyk

Navel orangeworm, Amyelois transitella (Walker), is one of the most important economic pests of walnut grown in California. Damage results when navel orangeworm larvae infest nuts following hull split prior to harvest. Economic loss to the walnut industry due to navel orangeworm was estimated at 12 million dollars in 1990 and 9 million dollars in 1991.

A year-long control program, is required to manage navel orangeworm. Because navel orangeworm cannot infest sound, uninjured nuts during the growing season, growers prevent in-season population development by minimizing nut injury from insect, disease, and physical damage which provides entry sites for infestation. Once hull split occurs, providing natural access to the nut, navel orangeworm management requires growers promptly harvest the crop to prevent infestation. Following harvest, orchard and equipment sanitation, removal of trash nuts from huller/dehydrator, and destruction of unharvested nuts are recommended to remove sites where navel orangeworm larvae and pupae overwinter. This procedure reduces the number of overwintering navel orangeworm and potential for infestation the following year.
The orchard sanitation practice is one of the most important components of the navel orangeworm management and control program for walnut. Orchard sanitation includes shaking the trees during the dormant season to remove previously unharvested "mummy" walnuts. Following shaking, it is further recommended that nuts be shredded to destroy the protection offered to navel orangeworm by the walnut shell.

Not all walnut growers have shredders capable of destroying the nuts and must rent or contract for this service. Moreover, shredding is not always compatible with a grower's cultural program; e.g. in cultivated orchards, uneven ground and clods can preclude complete destruction of the nuts. Other orchard floor management strategies and their effect on navel orangeworm survival within the nut, e.g. laying nuts in sod or weeds throughout the winter or discing mummy nuts into the soil, have not been explored. If such practices were effective in destroying overwintering navel orangeworm, growers would have additional flexibility in orchard sanitation practices. Here we report the results of a two-year study that evaluates effect of these other two orchard management practices on survival of overwintering navel orangeworm in mummy walnuts on the orchard floor.

METHODS

The experiment was conducted during the winter and spring of 1990/1991 and 1991/1992 in a mature 'Serr' walnut orchard in Porterville, Calif., with a history of economic navel orangeworm
damage. Navel orangeworm infestation in mummy walnuts was estimated in the experimental orchard each year. Each December, approximately 100 lbs of mummy nuts were collected from the orchard. Twenty random, ten nut samples were chosen from the entire lot. These samples were inspected for navel orangeworm larvae and pupae to estimate percent navel orangeworm infestation. In the 1990/1991 year, 27% of the nuts were infested with one or more navel orangeworm pupae or larvae; infested nuts had an average of 1.19 +/- 2.99 navel orangeworm larvae and pupae per mummy nut. In the 1991/1992 test year, 30% of the nuts were infested but with fewer insects per nut, .31 +/- .41 navel orangeworm larvae and/or pupae per mummy nut.

Following the estimate of navel orangeworm infestation, in 1990/91 250 randomly selected nuts and in 1991/1992 500 randomly selected nuts were submitted to one of four treatments: 1) nuts placed on a weed free 'berm' (to simulate weed-free, bare ground); 2) nuts placed in resident weed cover; 3) nuts placed on the orchard floor and shredded with a flail mower; and 4) nuts placed on the orchard floor and disced in two directions. Each treatment was replicated four times. Thus, according to pretreatment crack-out, approximately 300 navel orangeworm larvae or pupae in 1990/1991 and 200 in 1991/1992 were placed into each replicate of each treatment.

Nuts were submitted to their respective treatments on December 20 in 1990 and on December 4 in 1991 within the same orchard where they were collected. Following treatment, the nuts
were covered by a mesh pyramid cage, 1m x 1m square at the base and 1m high. Each cage was equipped with a 1 qt canning jar affixed to the apex of the pyramid to collect adult navel orangeworm moths. Following the discing treatment and cage placement, any nuts lying outside of the 1m x 1m dimensions of the cage were carefully placed under the cage in the same position relative to their depth of burial. Each cage was monitored for adult navel orangeworm emergence at two-week intervals during the winter. Once emergence began, cages were monitored weekly from March 29 through June 19, 1991, and from March 11 to June 3, 1992, for adult emergence. The average number of navel orangeworm adult moths that emerged were analyzed by ANOVA and means were separated by Duncan's Multiple Range Test, P=.05.

An additional sample of nuts was retained each year and held under ambient conditions in the laboratory for observation of adult navel orangeworm emergence and any parasite activity. In 1990/1991, 127 nuts, approximately 150 navel orangeworm larvae and pupae, and 1991/1992, 300 nuts containing approximately 81 larvae and pupae were reserved to observe emergence in the laboratory.

Rainfall was measured each year of the experiment. In the 1990/1991 test year very little rainfall occurred, and two midwinter irrigations were applied to simulate the approximately 10 inches of winter rainfall the area normally receives. In the 1991/1992 test year approximately 11 inches of rain occurred
which was a more normal rainfall pattern.

RESULTS AND DISCUSSION

LABORATORY EMERGENCE

In 1990/1991 36 adults and in 1991/1992 16 adults emerged under ambient laboratory conditions, approximately 24% and 20%, respectively, of the navel orangeworm population. No parasites emerged from the laboratory samples either year.

NAVEL ORANGEWORM SURVIVAL vs ORCHARD FLOOR MANAGEMENT

1991. Significantly higher navel orangeworm moth emergence occurred when mummy nuts were placed on the bare, weed-free berm than when placed either in weeds, disced, or shredded (see Table 1). Mummy nuts placed on the bare berm yielded an average of 63.3 adult navel orangeworm moths per replication. This compares with an average of 8.8, 2.3, and 0 navel orangeworm adult moths emerged from mummy nuts placed in weeds, disced, or shredded respectively. Percent recovery from the initial population was 21%, 3%, 1% and 0% respectively.

1992. As in 1991, highest emergence occurred when mummy nuts were placed on the bare, weed-free berm. However, unlike 1991, no significant difference in emergence was detected between nuts placed on the bare berm or in weeds. Adult navel orangeworm emergence from nuts placed on the bare berm or in weeds was significantly higher than when nuts were disced or shredded.
Average moth emergence from shredded nuts was significantly lower than those disced up (see Table 1). Nuts placed on the bare berm or in weeds averaged 11.8 and 9.0 moths per replication respectively. Emergence from shredded mummy nuts was 0.3 (one nut was found intact following the shredding treatment); whereas, disced nuts yielded an average of 3.8 moths per replication. Percent recovery from the initial population was very low, 5.9% (berm), 4.5% (weeds), .2% (shred), and 1.9% (disc), compared with 1991. It is unknown why this discrepancy occurred. In the 1991/1992 winter, temperature and rainfall conditions were relatively normal and temperatures more moderate than 1990/1991 when a severe freeze occurred in mid-December following placement of the nuts in the orchard. Interestingly, under laboratory conditions, navel orangeworm adult emergence was relatively similar each year.

These results are unlike those obtained for almond, a fruit that has a relatively soft shell compared with walnut. Little navel orangeworm survival occurred in mummy almonds allowed to remain in a weedy cover throughout the winter. Discing also resulted in considerably better navel orangeworm mortality in almond than walnut (C. E. Curtis & R. L. Coviello. 1972. Navel orangeworm in almonds. Western Fruit Grower). The thicker walnut shell apparently offers considerably more protection than that of almond.
CONCLUSIONS

Winter orchard sanitation is an essential component of navel orangeworm management in walnut orchards. However, simply removing mummy nuts from the trees does not destroy overwintering larvae and pupae and prevent subsequent adult emergence. Our data show that adult navel orangeworm readily emerge from intact nuts shaken from the trees and allowed to remain on a dry, weed-free orchard floor. Shredding mummy nuts following their removal from the trees essentially eliminates all navel orangeworm survival. Discing nuts into the soil, or allowing nuts to remain in a weedy cover, reduces emergence but does not eliminate it; a certain number of nuts in either situation probably remain exposed and relatively dry allowing navel orangeworm to survive.

Our data offer little flexibility in management of mummy nuts to eliminate navel orangeworm overwintering, once shaken from the trees. Shredding remains the only viable method of ensuring complete destruction of larvae and pupae in walnut sanitation program.

^G. Steven Sibbett, UC Farm Advisor, Tulare County
R. Van Steenwyk, UC Extension Entomologist, Berkeley
TABLE 1. Effects of various mummy nut destruction techniques on overwintering ability of navel orangeworm in walnuts

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean number of emerged navel orangeworm adults*</th>
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<tbody>
<tr>
<td></td>
<td>1990/91</td>
</tr>
<tr>
<td>Nuts placed on bare berm</td>
<td>63.3 a</td>
</tr>
<tr>
<td>Nuts placed in weeds</td>
<td>8.8 b</td>
</tr>
<tr>
<td>Nuts shredded</td>
<td>.0 b</td>
</tr>
<tr>
<td>Nuts double disced</td>
<td>2.3 b</td>
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*Numbers followed by the same letter in columns are not significantly different at P=.05 DMRT.