ABSTRACT

A preliminary conclusion of the research is that there does not appear to be significant genetic differences in developmental times between the codling moth populations in walnuts and apples. Codling moths were collected from walnuts and placed onto artificial diet as a rearing medium. Data obtained from these individuals were consistent with the data obtained from colonies of codling moth collected on apples. Similarly, codling moths which were successfully reared on walnuts did not demonstrate significant changes in developmental time. The number of larvae used in the trial was limited due to problems with rearing codling moth on walnuts in environmental growth chambers.

Significant differences in diapause emergence curves did appear to exist for apple and walnut codling moth populations. Codling moth populations in apples appear to peak approximately 2 weeks prior to populations in walnuts. If this phenomenon remains consistent next season, then two diapause emergence models will have to be constructed for codling moth.
OBJECTIVES

The existence of genetically different host races was originally proposed by Phillip and Barnes (1975) for populations in plum, walnut, and apple. These populations were reported to have different biological characteristics and behavior. These traits include differences in diapause breaking conditions, developmental rates, and ovipositional preferences. If these differences are real, then the populations in walnuts and apples may have to be managed differently in terms of the timing of various control strategies. One obvious area where these differences could become important is in the use of the codling moth phenology model developed for apple populations. Given the variability in the success of the model in different geographic regions, the possibility of geographic strains also existed. The objectives of the research are as follows: 1) to determine if codling moth populations in different parts of California have different developmental rates 2) to examine the flight temperature thresholds for the different geographic races and 3) to determine the relative importance of host races of codling moth for apples and walnuts. The main questions addressed by the proposal is "What are the differences between the different populations of codling moth and are these differences significant to the management of codling moth?".

PROCEDURES

Seasonal Phenology of Codling Moth in Walntus and Apples

Five pairs of orchards were selected in the Hollister area; each pair was composed of adjacent walnut and apple orchards. Pheromone traps were placed within each orchard and monitored for the entire growing season. Similarly, temperature records were taken in two locations within the trapping region. Previous studies attempting to compare seasonal phenology were forced to compare geographically separate regions. Given the pairing of the orchards much of the environmental variability can be taken into account by the statistical design.

Growth Chamber Studies

The possibility of geographic strains having differential developmental times is most easily explored by rearing all strains on artificial diet. Colonies of codling moth were reared from walnuts collected in Visalia, Hollister, and Chico. Another colony was collected from apples from the Watsonville area. One hundred newly emerged larvae from all colonies were placed into environmental chambers and allowed to develop within artificial diet cups. Each cup is checked on a daily basis for emergence of an adult moth. The number of degree-days required for completion of the life cycle can be calculated from the number of days to emergence and the temperature of the growth chamber. The use of artificial diet allows the elimination of the
host as a variable for determining developmental times.

Similarly, the influence of the host on developmental times can be explored by rearing the larvae on the different hosts. The various colonies were also maintained on the host from which they were collected, e.g. the Visalia strain was kept on walnuts. This rearing procedure is limited by the availability of the host in the field. Walnuts collected from the field and kept in cold storage do not appear to be acceptable for continuous rearing. Problems with mold and desiccation of the nutmeat proved to be the greatest problem with rearing the larvae. Larval mortality is extremely high when reared on walnuts despite the drilling of holes into the walnut shell and direct insertion of newly emerged larvae onto the nut meat.

RESULTS

Seasonal Codling Moth Phenology

The populations of codling moth in apples appeared to break diapause approximately 2 weeks earlier than the populations in walnuts as evidenced by the timing of the peak moth flight. The seasonal curves of the flights for the various pairs are shown in Figures 1-4. If the trap data are averaged from all five walnut orchards and compared to the average trap catches of the five apple orchards, the trend is more easily discerned (Figure 5). Further analysis of the spray programs will have to be done prior to any firm conclusions, but the evidence does suggest distinct population differences. One ramification of this data will be the need to construct two diapause-emergence models which have to date not been successfully developed for either apples or walnut populations. The differences between strains were not as apparent later in the season as the overlap between generations became increasingly larger.

Laboratory Studies

Studies are currently being conducted to compare the developmental rates of the 4 strains when placed on artificial diet. Data from the Visalia strain has shown a combined developmental time for the larval and pupal stage to be 784 degree-days at 78 F. Whereas this value appears to be less than the value currently being used in the phenological model, the data does not appear to be outside of normal statistical variation observed in the literature (Table 1). The remaining colonies are just now emerging and should be tabulated prior to the Walnut Conference. A preliminary conclusion is that the failure of the model to accurately predict codling moth phenology in all situations is not a reflection of differential developmental rates. Some other variable which remains to be identified appears to be introducing the unexplained variation.

Data obtained by rearing codling moth in walnuts showed an average developmental rate of 792 degree-days under constant temperature conditions (Table 1). However, the mean only represents 9 successfully reared larvae due to problems with rearing codling moth on walnuts in the laboratory. Further studies will attempt to rear codling moth on walnuts in the orchard. When larvae were reared under fluctu-
ating temperatures in growth chambers on apples and walnuts, a decrease in the required number of degree-days was observed. These data are consistent with other data presented for other insects in the literature. The developmental times were approximately 25% less under fluctuating temperatures than constant temperatures. Further trials will be required to verify this phenomenon.

CONCLUSIONS

The failure of the model in some cases does not appear to be due to differential developmental times on different hosts. The data collected from codling moths collected from walnuts and reared on diet appears generally consistent with the literature. Data generated under constant temperature conditions may prove to be unreliable if the fluctuating temperature data remains consistent after further trials. If the data under fluctuating temperature conditions proves reliable, then the fit of the model with both data sets will be compared.

The existence of codling moth host races appears to be a reasonable, preliminary conclusion based on the overwintering emergence curves. Given that the model is started by the first significant male moth flight, this phenomenon should not change the predictive abilities of the model.
Number of Codling Moths/Trap/Week

Figure 1

Number of Codling Moths/Trap/Week

Figure 2
Figure 5

Number of Codling Moths/Trap/Week

ALL ORCHARDS

[Graph showing the number of codling moths per trap per week from Julian days 50 to 270. The graph compares data from Walnut and Apple orchards.]

Figure 5
Table 1. Effects of temperature on the development of codling moth under various rearing conditions

<table>
<thead>
<tr>
<th>Rearing Medium</th>
<th>N</th>
<th>Degree-days</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Range</td>
<td></td>
</tr>
<tr>
<td>Artificial Diet</td>
<td>75</td>
<td>784 °D</td>
<td>702-988 °D</td>
<td></td>
</tr>
<tr>
<td>(walnut strain)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walnuts</td>
<td>9</td>
<td>792 °D</td>
<td>726-1092 °D</td>
<td></td>
</tr>
<tr>
<td>Apples</td>
<td>19</td>
<td>796 °D</td>
<td>682-1204 °D</td>
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<td>1</td>
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</tr>
<tr>
<td>Apples</td>
<td>16</td>
<td>605 °D</td>
<td>480-900 °D</td>
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</tr>
</tbody>
</table>

1 Codling moth reared under fluctuating temperatures between 84 °F and 46 °F.