Effects of Orchard Host Plants on the Oviposition Preference of the Oriental Fruit Moth (Lepidoptera: Tortricidae)

CLAYTON T. MYERS, LARRY A. HULL, AND GRZEGORZ KRAWCZYK

Department of Entomology, Fruit Research and Extension Center, The Pennsylvania State University, 290 University Drive, Biglerville, PA 17317


ABSTRACT Recently, the oriental fruit moth, Grapholita molesta (Busck) (Lepidoptera: Tortricidae), has emerged as a major problem on apples (Malus spp.) grown in the mid-Atlantic and midwestern United States, despite its historically important and frequent occurrence as a peach (Prunus spp.) pest. It is possible that host-driven biological phenomena may be contributing to changes in G. molesta population dynamics resulting in outbreaks in apple. Studies were designed to examine the effects of host plants on oviposition behavior, in an effort to clarify the host association status of eastern U.S. populations and also to gain insight into how pest modeling and management efforts may be altered to take into account various host-associated effects. G. molesta adults exhibited ovipositional preference for nonbearing peach trees over nonbearing apple trees in close-range choice tests conducted in the field, regardless of the larval host origin. A significant preference for peach shoots over apple shoots was observed on six of 12 sampling dates with a wild G. molesta population at the interface of adjacent peach and apple blocks. Numbers of eggs found on apple fruit were higher after peach fruit were harvested and apple fruit began to approach maturity (during the flight period for third and fourth brood adults). Possible implications for population modeling and integrated management of G. molesta are discussed.

KEY WORDS oriental fruit moth, apple, peach, oviposition behavior, population dynamics

Oriental fruit moth, Grapholita molesta (Busck) (Lepidoptera: Tortricidae), is a major pest of tree fruits throughout the world. Historically, in the eastern United States, oriental fruit moth has rarely been a major pest of commercial apples (Malus spp.) and was generally controlled by the use of broad-spectrum insecticides (Hull et al. 2001). However, since 1998, well more than 1,700 total loads of fruit (mostly apples) from the mid-Atlantic region have been rejected by fruit processing plants in Pennsylvania and West Virginia because of the presence of live G. molesta larvae (Krawczyk and Hull 2005).

One possible reason for these recent outbreaks is that G. molesta population dynamics may be affected by host-driven processes. Host race formation has been demonstrated in the codling moth, Cydia pomonella (L.), a related tortricid pest of apple (Phillips and Barnes 1975, Barnes 1991) as well as in the fruittree leafroller, Archips argyrospila (Harris) (Goyer et al. 1995). In other tortricids, host plant species (or even cultivars) have been shown to affect various aspects of insect development. In the oblique-banded leafroller Choristoneura rosacea (Harris), host plant cultivar, phenology, and leaf age significantly affected survival (Onstad and Reissig 1986).

Host-driven factors can affect populations that are not separable into distinct host-related biotypes. Populations that are affected (but not reproductively isolated) by host plants are referred to as "ectomorphs" (Pasley 1993). Oriental fruit moth development and reproduction are affected by host plants (Myers 2005). Early and recent work (Peterson and Haeussler 1988, Myers 2005) confirms that larvae develop faster on peach (Prunus spp.) than on apple. Also, fecundity is affected by the host plant of larval origin (Myers et al. 2006). If peach and apple host plants exert similar differential developmental effects on wild populations of G. molesta, it could affect their development and behavior in ways that affect population dynamics, which has been previously hypothesized as a problematic issue for oriental fruit moth management (Allen and Brunson 1943).

From an ecological standpoint, an expressed adult oviposition preference for the host plant of larval origin could provide the basis for reproductive isolation via ecological separation and potentially allow for further divergence, host race formation, or both (Bush 1969). Because dispersal capability of larvae is very low, most larvae are obligated to feed on the plant part upon which they hatch, and even very near to...
the point of neonatal hatch (Peterson and Haeussler 1930). Indeed, most larvae only remain on the plant surface for $\sim 2$ h, and after acceptance of the host plant based on olfactory cues (Bouzouane et al. 1987), generally begin feeding and enter the plant within a few hours of hatch (Allen 1988, Myers 2005). Oviposition behavior in *G. mola*sta has been described previously (Garman 1918, Cory and McConnell 1927, Peterson and Haeussler 1930, Sarai 1970, Reichart and Bodor 1972, Rothschild and Vickers 1991), but studies investigating *G. mola*sta host preferences in the field have not been reported.

In Pennsylvania orchards, peach and apple blocks are often planted adjacent to one another and multiple blocks are well within the dispersal range (100–300 m) of *G. mola*sta adults. Some adults exhibiting maximal flight capacity $\geq$1 km (Yetter and Steiner 1931, 1932; Steiner and Yetter 1933; Hughes and Dorn 2002). If local *G. mola*sta populations consist of two (or more) host races that exhibit ovipositional preference for one host over another, it could significantly affect behavior patterns of adult moths, thereby leading to different strategies for managing the pest between peaches and apples. If host races are not present, there still may be an ovipositional preference exhibited by populations seasonally (i.e., preference for peach in the spring that shifts toward apple in the fall). Such seasonal effects could impact any given wild *G. mola*sta population, and knowledge of such effects could help pest management practitioners to predicatively model moth movement between blocks and more accurately targeted control tactics at various times of the season.

This article reports on experiments designed to address the following questions: 1) Does oviposition preference of a given *G. mola*sta population vary over the growing season? 2) Does the host plant of larval origin affect the oviposition preference of the adult? More specifically, is adult oviposition choice affected by rearing of larvae for a single generation on a different fruit media? Is adult oviposition choice impacted by the host plant of origin in wild populations (i.e., testing a population derived from peach versus a population derived from apple)? and 3) Does a wild *G. mola*sta population on the border interface of an apple and peach block exhibit oviposition preference?

**Materials and Methods**

**Experimental Site and *G. mola*sta Colonies.** All studies were conducted in experimental orchards at the Pennsylvania State University Fruit Research and Extension Center (PREC), Biglerville, PA. Female moths used in all studies were derived from colonies of *G. mola*sta collected from local orchards in 1997–2002. Founder individuals were collected from infested peach orchards as well as from rejected peach and apple fruit from local processors during the 1997–1998 growing seasons. For the 2003 releases of “host-associated” colonies in the oviposition preference study, founder individuals were collected from two local commercial orchards in late summer and fall 2002. The individuals from peach were collected in summer 2002 from infested terminals in a somewhat isolated (i.e., $\leq$ 500 m from other host plants) commercial peach block, near Arendtsville, PA. Individuals from apple were collected from infested fruit in a commercial apple orchard near Ortanna, PA, which was also relatively isolated from other host plants ($\leq$500 m).

**Colony Rearing Procedures.** Once each population was collected and brought into the laboratory, larvae were removed from plant material and placed in large plastic feeding trays ($\sim$6 by 72 cm) containing $\sim$1,000 g of a meridic lima bean diet (Meagher 1985). These containers were maintained either in growth chambers or on the countertop space in the laboratory at $\sim 22 \pm 2 ^\circ$C on a photophase of 16:8 (L:D) h. Larval development was completed within 10–14 d. As larvae neared the prepupal stage, strips (1–3 cm in width) of corrugated cardboard were placed on top of the media in the feeding trays to provide sites for pupation. Pupae were removed and placed into rectangular, wood-framed mating chambers ($\sim$30 by 42 by 12 cm) that were lined on one side with wax paper. After emergence, the adults mated within the chambers and females oviposited on the wax paper lining. These chambers contained a cotton wick placed in a vial of 10% honey solution that served as a food source for adults. Wax sheets filled with 5,000–7,000 eggs were removed daily and placed in the containers with the lima bean diet. Larvae from the peach and apple colonies were reared for $\sim$ 8 and 14 mo, respectively, on lima bean diet ($\sim$8 and 14 generations, respectively).

**Experiment 1: Caged Tree Choice Studies.** Laboratory Colony, 2002, 2004. Close-range, caged tree choice tests were conducted in a mixed species, young orchard with nonbearing peach ('Loring') and apple ('York Imperial') trees. Peach trees were on Lovell rootstock and were planted in spring 2000. Apple trees were on Malling 9 rootstock and were planted in spring 2001, adjacent to the peach trees. Tree height was $\sim 1.5$ m for both peach and apple, with some variability. Apple trees were planted randomly, in geospatial relation to peach trees (i.e., approximately one-half were planted north relative to its respective peach tree, and one-half were planted on the south side). Trees were fertilized as needed and were treated with protectant and eradicant fungicides (metiram, mancozeb, captan, mylobutanil, and/or thiophanate methyl throughout the experiments) on a standard prophylactic schedule to protect trees from apple scab and other seasonal diseases. Trees in the same block not in use for a given insect release study also were sprayed with protectant insecticides (azinphosmethyl, phosmet, methomyl, or a combination) to prevent inordinate infestation from endemic *G. mola*sta populations as well as other tree fruit pests. Trees that were used for the close-range choice tests were not treated with insecticides for 14–20 d before each release of adult moths.

Adjoinedly planted pairs of peach and apple in the block were enclosed within a durable, white mesh fabric material (product 3149, Fablok Mills Inc., Murray Hill, NJ). The material was cut from a roll to the
appropriate length for two young fruit trees. Velcro tape was applied and fastened with staples to the outer ends of the material. When the mesh was folded over the two trees, the tape served to attach the two sides underneath the trees and form an “envelope” to enclose trees. Lateral sides of the envelope were tied shut with plastic zip ties, leaving the trees caged within the plastic mesh. Wooden stakes with crossbars were driven into the ground next to the paired trees to provide further support and to relieve trees from the weight of the mesh cage. The tape connection on the lower side of the cage, underneath the trees, was easily pulled apart for the purpose of releasing moths inside the mesh cage. Trees were caged 2 to 3 d before release of moths to prevent oviposition from wild populations before release of experimental moths.

Ten virgin female and 10 virgin male moths were collected for each release from the colony via removal and isolation of pupae from diet feeding trays. Isolated pupae were stored in a growth chamber (22°C and a photoperiod of 16:8 [L:D] h). Adults were transferred within 48 h of emergence into plastic containers in groups of 10 females and 10 males. Containers with adults were then stored in a Styrofoam cooler for transportation to the orchard and release into the cages. Each container of adults was placed inside its respective mesh cage. Once inside the cage, the plastic container was opened and shaken, allowing moths to fly freely into the cage. The cage was immediately released to prevent moth escape. Placement of moths in the cages was always done within 3 h of either sunrise or sunset to avoid desiccation of adults by intense, midday sun. In addition, care was taken to avoid release of insects when major precipitation events were occurring or were forecasted to occur within 24 h. For each release, the date was related to accumulated degree-days (°C) past biofix (date of first sustained male moth capture in a pheromone trap placed in a nearby orchard), based upon an established developmental model, base 7.2°C, maximum 92.2°C (Hull et al. 2001). Releases were timed to approximately coincide with generational emergence of G. molesta in area orchards (i.e., first, second, and third/fourth flights), although some deviation from these emergence periods was inevitable.

Once placed in the cages, moths were allowed to freely mate and oviposit. Moths were left in cages for 7–14 d, depending on temperature. Timing was estimated based on temperature and visual inspection of the cages for flying moths. After this period, cages were removed, and leaves were sampled from each tree. A uniform proportion of leaves were picked from each tree to eliminate any bias because of the size of the tree and number of leaves. In 2002, for the first release, 20% of leaves (every fifth leaf) were sampled on each tree. For all subsequent releases, 50% of leaves (every other leaf) were sampled. Leaves were taken to the laboratory for examination and counting of G. molesta eggs.

Eggs were scored as hatched or unhatched. Only unhatched eggs were analyzed for this study, because it was assumed that hatched eggs could have been present on the trees because of prior oviposition from wild populations. Although it is possible that some eggs laid on the tree may have hatched before counting (thus running the risk that oviposition by released moths may be sometimes undersampled), it was decided that only unhatched eggs should be analyzed to ensure that conclusions were not affected by analysis of oviposition that may have occurred before caging of the tree. Leaves were examined on both the upper and lower surfaces for eggs. Because of the time-consuming nature of this examination, leaves were stored in a refrigerator until they were counted, to prevent larval hatch from freshly laid eggs. Six tree pair replicates were used for each release (with the exception of the second release in 2002, where only three replicates were used). Three releases were made each season in 2002 and 2004.

Counts of unhatched G. molesta eggs were analyzed using two methods. The first method was a calculation of mean numbers of eggs per host tree, based upon the six replicates. Differences were analyzed using a paired t-test, with an α value of 0.05. The second method was analysis by comparing the pooled proportion of eggs laid, using a Z-test, with the null hypothesis that the proportion found on either host would be 50%. If the proportion of eggs found on a host was significantly >50% (with an α level of 0.05), then the null hypothesis was rejected and the alternative hypothesis of a host preference was supported (Zar 1999, Minitab, Inc. 2000).

Experiment 2: Caged Tree Choice Studies: Host-Associated Colonies, 2002–2003. In 2002, individuals from the laboratory G. molesta colony were reared for one generation on fruit hand picked from peach (Loring) or apple (York Imperial) trees at the laboratory that were not treated with insecticides. Fruit were washed with soap and warm water, rinsed, air-dried, and placed into plastic trays for larval feeding. Wax paper sheets containing eggs from the laboratory colony were placed in the feeding trays to hatch. Feeding trays were capped with plastic lids, placed on counter space in the laboratory (ambient temperature of 22°C), and larvae were left to feed freely anddevelop. As larvae neared the prepupal stage, corrugated cardboard strips were placed in the feeding trays to provide a pupation site. Pupae were later collected and segregated by sex and by host as in the first study. Groups of moths were released into caged trees as in experiment 1. There were three replicate tree pairs for the adults reared from peaches and three replicate pairs for the adults reared from apples. Methods for placement in cages, egg sampling, leaf storage, egg counting, and data analysis were the same as for experiment 1.

Additionally, host-associated colonies were established from local populations collected from an isolated peach site collected in summer 2002 and an isolated apple site collected in fall 2002, for use in a similar close-range oviposition assay. The apple colony was reared for ~8 mo (~8 generations) on mericic diet in the laboratory, whereas the peach colony
Table 1. Ovipositional preference of oriental fruit moths released in cages with apple and peach trees

<table>
<thead>
<tr>
<th>Yr</th>
<th>Release*</th>
<th>n^b</th>
<th>Mean (± SEM) no. unhatched eggs</th>
<th>Proportion unhatched eggs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Peach</td>
<td>Apple</td>
</tr>
<tr>
<td>2002</td>
<td>1-14 May</td>
<td>6</td>
<td>5.7 (2.3)</td>
<td>1.7 (0.8)</td>
</tr>
<tr>
<td></td>
<td>2-5 July</td>
<td>3</td>
<td>16.0 (10.6)</td>
<td>3.0 (0.6)</td>
</tr>
<tr>
<td></td>
<td>3-14 Aug</td>
<td>6</td>
<td>4.5 (1.0)</td>
<td>1.5 (0.7)</td>
</tr>
<tr>
<td>2004</td>
<td>1-6 May</td>
<td>6</td>
<td>1.0 (0.5)</td>
<td>0.3 (0.2)</td>
</tr>
<tr>
<td></td>
<td>2-14 June</td>
<td>6</td>
<td>7.8 (4.3)</td>
<td>0.8 (0.5)</td>
</tr>
<tr>
<td></td>
<td>3-22 Aug</td>
<td>6</td>
<td>20.0 (8.9)</td>
<td>6.5 (2.8)</td>
</tr>
</tbody>
</table>

Proportion values within the same row followed by the same letter are not significantly different by Z-test (P > 0.05).

* Date of release and degree-days past biofix.

^b n is number of replicate tree pairs.

was reared for ≈12–14 mo (≈12–14 generations) on meridic diet in the laboratory. Adults from each colony were released into paired trees over the course of three releases (similar timing as experiment 1) to see whether moths from host-associated populations behaved similarly to moths from the laboratory colony. For each release, three replicate tree pairs were used for the adults from the peach colony, and three replicate pairs for the adults from the apple colony. Methods for placement in cages, egg sampling, leaf storage, and egg counting, were the same as for experiment 1. Differences were analyzed by comparing the pooled proportion of eggs laid, using a Z-test as described previously.

Experiment 3: Field Sampling for *G. mosaica* Eggs on an Apple–Peach Interface, 2004. An orchard-level sampling study was conducted at the interface of an 1.5-acre apple orchard that was not treated with insecticides and an 1.5-acre peach orchard that was divided into subplots for a separate experimental insecticide efficacy study. Less than 50% of the trees in the peach orchard received any insecticides. The apple orchard was a mixed block of 31-year-old trees of York Imperial and ‘Golden Delicious’ trees on M.26 and M.7 rootstocks, respectively. York Imperial and Golden Delicious trees were interplanted in four tree plots, with alternating cultivars in each plot. The peach orchard was a mixed cultivar block of ‘Beekman’, ‘Autumn Glo’, ‘Sun Glo’, and ‘Redhaven’ trees that were 9 yr old. Cultivars were planted in rows to provide trees for other insecticide efficacy experiments. The row that bordered the adjacent apple block was comprised of only Beekman trees that were not treated with insecticides. Trees were sampled on the outer rows at the interface of the two adjacent orchards for *G. mosaica* eggs.

On 20 and 27 May, 20 trees were sampled in each block, along the peach–apple interface. Peach trees were all sampled from Beekman trees on the outer row. Apple trees were sampled from the first two rows and consisted of 10 York Imperial trees and 10 Golden Delicious trees. Shoot leaves on all sampled trees were visually inspected for 5 min per tree, and all eggs (hatched and unhatched) were counted equally.

From 9 June to 26 August, 10 Beekman trees in the interface row of the peach block and 10 apple trees in the interface row of the apple block (five York Imperial and five Golden Delicious trees) were sampled weekly for presence of *G. mosaica* eggs. On peach trees, a 3-min visual search was conducted on shoot leaves (i.e., leaves on a growing terminal) along with a subsequent 3-min search of fruit leaves (i.e., leaves adjacent to a fruit). The only exception was the 26 August sample of peach fruit leaves, which was conducted on Autumn Glo trees in the second row of the block, because there were no fruit left on the Beekman trees in the first row. For all samples of apple trees, a 3-min visual search was conducted on shoot leaves only. Subsequently, 10 fruit were picked at random from each tree and examined for eggs. Eggs were scored as either hatched or unhatched for all samples. Differences between mean numbers of total eggs on samples from peach shoot leaves and apple shoot leaves were analyzed using an unpaired *t*-test (*α* < 0.05) (MINITAB, Inc., 2000). Numbers of eggs found on apple fruit were analyzed by sampling date using a one-way analysis of variance (ANOVA), and means were separated using Fisher protected least significant difference (LSD) test (*P* < 0.05) (SAS Institute, 2000).

Results

Experiment 1: Caged Tree Choice Studies: Laboratory Colony, 2002, 2004. There was no difference in the mean number of unhatched eggs found between apple and peach trees for any releases of adults in close-range choice tests conducted in 2002 and 2004 (*t* = 1.98, 1.23, 1.90, 1.08, 1.63, and 1.93 and *P* = 0.013, 0.324, 0.116, 0.328, 0.163, and 0.109, respectively) (Table 1). However, when comparing overall pooled proportions, there was a strong preference (three-nine-fold) for oviposition on peach trees over apple trees for all release dates during both years (Table 1). The paired *t*-test method compared means via ANOVA for related samples (i.e., leaves from paired trees in the same cage), whereas the Z-test simply compared the total proportion of eggs laid on a given host without taking into account the variation between replicate pairs (Zar, 1999, MINITAB, Inc., 2000).

Experiment 2: Caged Tree Choice Studies: Host-Associated Colonies, 2002–2003. There was no difference in the mean number of unhatched eggs found between apple and peach trees among individuals reared for either one generation on either peach or
apple \( (t = 2.22 \text{ and } 1.88, \text{ and } P = 0.157 \text{ and } 0.201, \text{ respectively}) \) (Table 2). When pooled proportions were compared, both groups of moths had an overall oviposition preference for peach, similar to the results of the 2002 and 2004 releases of diet-reared individuals (Table 2). *G. m. moles*ta adults derived from an isolated peach orchard and an isolated apple orchard exhibited ovipositional preferences for peach trees with one exception. In the first release of 2003, adults derived from an apple orchard exhibited ovipositional preference for apple, whereas adults derived from a peach orchard exhibited preference for peach (Table 3).

**Experiment 3: Field Sampling for *G. m. moles*ta Eggs on an Apple–Peach Interface, 2004.** In an early season assessment (20 May) of oviposition by a wild *G. m. moles*ta population near a peach–apple interface, more eggs were found on peach shoots (1.7 eggs per tree) than on apple shoots (0.0 eggs per tree) \( (t = 4.34, \text{df} = 19, P < 0.001) \). There was no significant difference in total egg numbers between peach (1.0 eggs per tree) and apple (0.1 eggs per tree) on the following week (27 May) despite a 10-fold numerical difference in means \( (t = 1.64, \text{df} = 19, P = 0.116) \). Subsequent sampling, which was conducted weekly until 26 August showed that there was significantly higher oviposition on peach shoot leaves than on apple shoot leaves at six of 12 sample dates \( (t = 1.00, 3.00, 3.71, 1.50, 3.50, 6.71, 1.79, 3.99, 4.39, 2.09, 2.20, \text{ and } 2.12 \text{ and } P = 0.343, 0.015, 0.005, 0.168, 0.007, < 0.001, 0.107, 0.003, 0.002, 0.067, 0.055, \text{ and } 0.053 \text{ on 9 June, 17 June, 23 June, 1 July, 8 July, 15 July, 22 July, 29 July, 5 August, 11 August, 19 August, and 26 August, respectively} \) (Fig. 1).

Total numbers of *G. m. moles*ta eggs found on apple fruit increased over the course of the study \( (P = 3.40; \text{df} = 11.108; P < 0.001) \), with the highest egg densities observed on 26 August. The density of eggs per fruit was significantly higher on both 19 August and 26 August than on earlier samples taken on 23 June and 1 July (Fig. 2). Numbers of *G. m. moles*ta eggs found on peach fruit leaves (i.e., leaves directly adjacent to a fruit) were variable over the season.

**Discussion**

In caged tree choice studies, there was a considerable amount of variability in the level of preference between replicates of paired trees. This high level of experimental error between replicates contributed to the poor statistical separation of means between peach and apple. This pattern occurred throughout all the close-range caged tree studies and is likely indicative of a possible procedural or design issue with the studies. Therefore, interpretation of such data must be done cautiously. Care was taken to eliminate directional bias, because it has been speculated that solar position could affect ovipositional behavior (Salles and Marini 1989). Thus, one-half of the tree pairs used in the study had the apple tree placed south of the peach, and one-half of the pairs had the opposite orientation. Examination of data based upon these factors showed no evidence of a directional effect.

Phillips and Proctor (1969) reported high levels of variability in oviposition by *G. m. moles*ta females in caged tree studies, with some females laying no eggs. Whereas both female and male adults may mate more than once, they rarely mate more than once within a given 24-h period (Dustan 1964). Thus, it is possible that consecutive days with cool and/or wet weather (i.e., days with temperatures below the normal threshold for adult activity) may have caused mating to be significantly delayed, which lowers fecundity and fer-

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**Table 3. Ovipositional preference of host-associated* oriental fruit moth* released in cages with apple and peach trees, 2003**

<table>
<thead>
<tr>
<th>Releasea</th>
<th>Host origin</th>
<th>nb</th>
<th>Peach</th>
<th>Apple</th>
<th>Proportion unhatched eggs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–23 May 2003 (392)</td>
<td>Peach</td>
<td>3</td>
<td>0.74a</td>
<td>0.29a</td>
<td>0.001</td>
</tr>
<tr>
<td>1–28 May 2003 (297)</td>
<td>Apple</td>
<td>3</td>
<td>0.26b</td>
<td>0.04a</td>
<td>0.035</td>
</tr>
<tr>
<td>2–5 July 2003 (580)</td>
<td>Peach</td>
<td>3</td>
<td>0.79a</td>
<td>0.21b</td>
<td>0.004</td>
</tr>
<tr>
<td>2–5 July 2003 (820)</td>
<td>Apple</td>
<td>3</td>
<td>0.92a</td>
<td>0.16a</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>3–22 Aug. 2003 (1,628)</td>
<td>Peach</td>
<td>3</td>
<td>0.90a</td>
<td>0.16b</td>
<td>0.021</td>
</tr>
<tr>
<td>3–25 Aug. 2003 (1,669)</td>
<td>Apple</td>
<td>3</td>
<td>1.00a</td>
<td>0.00b</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Proportion values within the same row followed by the same letter are not significantly different by Z-test \( (P > 0.05) \).

a Date of release and degree days past biofix.

b n is number of replicate tree pairs.
tility in *G. molesta* (Fraser and Trimble 2001). This may have resulted in very low levels of overall oviposition in some instances, especially in the early season releases.

There was no apparent evidence of a selection effect on adult host preference for oviposition after rearing for a single generation on either apple or peach. Cisneros and Barnes (1974) demonstrated that codling moth of various host origins had increased preference toward apple because they were reared continuously on apple, and this preference increased with consecutive generations of rearing on apple fruit. Their findings indicated a selection effect on larvae, and the authors ultimately hypothesized a genetically heritable trait for adult oviposition preference that was selected for by feeding on apple. Further studies are necessary to determine whether rearing continuous generations of *G. molesta* on a fruit substrate has an effect on oviposition preference.

With one exception out of three releases, adults from both apple and peach colonies exhibited an overall oviposition preference for peach trees over apple trees. It should be noted that for the first release when the apple colony exhibited preference for apple, the release of adults from the two colonies was separated by 2 d, because of different emergence timing from the respective colonies. In all other releases later in the season, *G. molesta* adults exhibited preference for peach, regardless of the original host origin of the colony.

It is unknown how laboratory rearing on meridic lima bean diet may have affected the genetic factors affecting host choice behaviors, via selection. In a closely related species, *Grapholita prunitora* (Walsh), rearing on a similar lima bean diet (Mantey et al. 2000) for five generations resulted in the development of a "golden sport" population that expressed heritable differences in wing coloration from the original wild strain (Mantey et al. 2000, Neven and Mantey 2004). It is difficult to compare the significance of a phenotypic color mutation in comparison with the mutation (or mutations) that would be necessary affect host preference, but this finding does underscore concerns about continuous rearing on meridic diet, and the effects on the genetics of host selection behavior.

If it could be assumed that the population genetics of *G. molesta* remained stable over the course of laboratory rearing, our results would indicate little selection pressure for wild *G. molesta* to preferentially oviposit on the host of larval origin, because individuals derived from both peach and apple exhibited similar host preferences as a long-established laboratory population. Additionally, dispersal between these two crops is very common for many *G. molesta* populations in the eastern United States, given the proximity of many plantings and the dispersal capacity of *G. molesta* adults (Yetter and Steiner 1931, 1932; Steiner and Yetter 1933; Allen and Branson 1943; Hughes and Dorn 2002). This situation (coupled with the presence of available wild hosts) would likely prevent long-term, continuous feeding on one particular host that could facilitate genetic isolation and formation of a host race. Taking these observations together, we hypothesize that the host-associated colonies of *G. molesta* observed in these studies were not genetically distinct host races. However, further rearing and backcrossing studies with multiple host-associated colonies with an amply broad geographic sample would need to be carried out to ascertain the true genetic makeup of these populations and others in the eastern United States.

Peach trees may be more attractive to *G. molesta* adults in nature than apple trees. One factor to consider in exploring this hypothesis is that all trees used in our close-range preference tests were nonbearing in 2002 and 2004. It is known that *G. molesta* adult females are attracted to volatiles from both peach and apple shoots (Natale et al. 2003) and fruits (Natale et al. 2004b), but no differences in attraction (i.e., preference) has been shown between the two hosts in the laboratory, when using a Y-tube olfactometer (Natale et al. 2004a). Olfactometer assays measure close range preferences, and it is difficult for predictive extrapolation at the orchard level based on these assays. At an orchard site, where a large, wild *G. molesta* population was present at the interface of adjacent peach and apple blocks, oviposition preference favored peach over apple on several sampling dates. Whereas *G. molesta* did not oviposit in large numbers on apple shoot leaves, oviposition on apple fruit was
observed and more eggs were laid on apple fruit late in the season than early in the season. This may be because of attractiveness of fruit volatiles that increase with fruit maturity. Fruit volatiles from apples have been shown to be attractive to both oriental fruit moth (Natale et al. 2004b) and codling moth adults (Hern and Dorn 1999) and have been shown to stimulate antennal responses (Ansebo et al. 2004) and elicit reproductive behaviors (Yan et al. 1999).

It was not possible to make valid statistical comparisons between numbers of eggs found on apple fruit versus numbers found on peach fruit leaves, because of differences in sampling protocol between the apple and peach trees. A fruit versus fruit (apple versus peach) comparison would also not have been useful, because G. molesta does not oviposit directly on peach fruit (Garman 1918). Oviposition on apple fruit increased as the season progressed and was especially high in mid- to late August. This increased oviposition activity was probably because of female movement from the adjacent peach orchard, after Beekman peaches were harvested in early to mid-August.

Sex pheromone trapping studies that monitored adult male activity indicated the potential for some seasonal movement of adults between hosts, but the magnitude and implications of such activity are not clear (C.T.M., unpublished data). Trends from other sex pheromone trap data (in both research and commercial blocks) indicate that very high numbers of adults emerge in the spring from the large overwintering larval populations in apple blocks (I.A.H. and C.T.M., unpublished data). These large overwintering populations are presumably present because of high levels of oviposition and subsequent survival of later generation larvae that result from their ability to feed and survive on apple fruit in the previous fall. Data from the current study indicates that adults at the interface of infested peach and apple trees may exhibit an early season preference for peach trees.

Combining the above-mentioned observations, one might infer that peaches near apple blocks may be particularly susceptible to early season migration from large spring emergences of G. molesta populations that overwintered in adjacent apples and thus may require more aggressive pest management approaches. Conversely, apple blocks bordering infested peach blocks could be very susceptible to late season migrations of adults leaving peaches for more attractive apple fruit. Such adult movement could be especially important given the dispersal capability of G. molesta females. More robust studies are needed to confirm these data, which would potentially improve our understanding of G. molesta behavior and dispersal and afford researchers an increased capacity to accurately model the population dynamics between adjacent blocks of different host plants.

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