Spatial Distribution of Plum Curculio Egglaying in Apple Trees

Jaime Piñero, Katie Bednaz, Amanda Ross, and Ronald Prokopy
Department of Entomology, University of Massachusetts

Determining the distribution of initial and subsequent plum curculio (PC) damage inflicted upon fruit within host tree canopies could aid in optimal placement of traps for monitoring PC, especially placement of branch-mimicking cylinder traps. Such knowledge may also aid in devising sound protocols for monitoring sectors of host trees most prone to receiving PC damage. Studies performed in past years (nearly all in Quebec and predominantly with caged trees) have yielded valuable but somewhat inconsistent results (perhaps due to differences in tree size, tree phenology, or adult PC population density). It has been found, for example, that PC damage is greatest at tops of large apple trees, but for semi-dwarf caged trees, PC damage has been reported as concentrated toward the center of the canopy. Here, at approximately one-week intervals in 2000, we compared the spatial distribution of PC infestation of fruit of small, medium, and large apple trees.

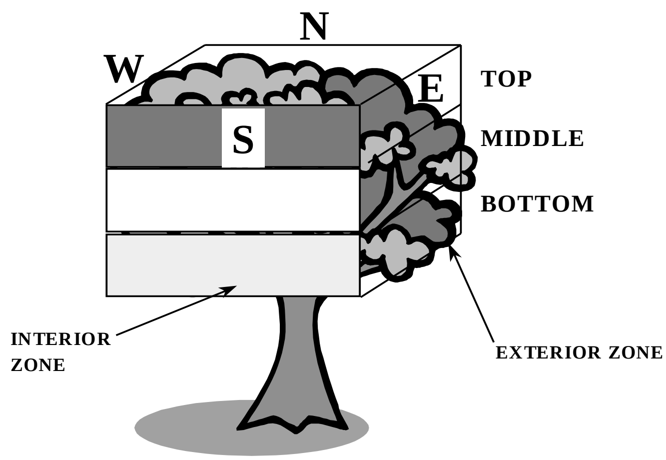

Figure 1. Representation of the subdivision of an apple tree canopy into three levels, showing the four limb orientations, and the exterior and interior zones of tree branches (only for medium and large trees). Twenty-four sampling points were used for medium and large trees and 12 for small trees.

Materials & Methods

Studies were conducted in unsprayed sections of two apple orchards (Horticultural Research Center and Atkin's Farm) located in Belchertown, MA. At the HRC, we sampled from six small (McIntosh/M.9) and four medium (Priscilla/M.26) trees. At Atkin's we inspected the fruit of six large (Cortland/M.7) trees. We divided tree canopies into bottom, middle, and top (vertical plane) sectors by selecting and marking branches at each level. Within each level, there were four branches, one each pointing West, South, North, and East. Each of the 12 branches per tree was in turn subdivided into an external and internal zone, except for small trees where (because of limited canopy breadth) fruit inspection was confined to the mid part of tree branches. This approach provided 24 sampling locations in large and medium trees and 12 sampling locations in small trees (Figure

Table 1. Schedule of fruit sampling (mean fruit diameter in parentheses).

Tree size	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Small	May 24 (6.5 mm)	May 31 (8 mm)	June 7 (10 mm)	---	---
Medium	May 23 (7 mm)	May 30 (10.5 mm)	June 9 (13 mm)	June 16 (22.5 mm)	June 22 (no meas.)
Large	June 2 (9 mm)	June 13 (no meas.)	June 20 (10.5 mm)	---	---

1). We inspected five fruit per sampling location (sector), recording the number of oviposition scars found on each fruit. Fruit inspection was conducted according to the schedule presented in Table 1. Fruit within a sector were sampled randomly on each sampling date. During the first two sampling dates, sampled fruit were mistakenly picked from small and medium trees. Thereafter, fruit were inspected *in situ* and remained on tree branches.

Results are presented in the form of mean number of oviposition scars per fruit and also as percentage of total fruit injured (fruit having at least one PC scar). Data were averaged across the number of replicates (trees) that comprised each treatment (tree size). Fruit were sampled on five dates for medium trees, and on three dates for small and large trees (because of the devastating impact of apple scab in mid- to late-June).

Results

Branch level. Distribution of PC damage according to branch level for each tree size and sampling date is depicted in Figure 2. For small trees, fruit damage was about the same for low, middle and top levels on each of the three sampling dates. For the first sampling, 3-8% of the fruit inspected had at least one oviposition scar. Percentages of fruit having one or more such scars increased gradually until reaching a maximum of 53-66% on the third (and last) sampling date. For medium trees, on the first sampling date, there were numerically but not significantly more PC scars on those fruit located at the top of the canopy. For sampling dates 2 and 3, oviposition scars were about evenly distributed among levels within the canopy. For sampling date 4, there were numerically but not significantly fewer scars near the top of the canopy, and during sampling date 5, fruit damage was significantly least at the top of the canopy. Percentages of fruit having at least one PC scar ranged from 6-16% for sampling dates 1 and 2, and increased substantially on the

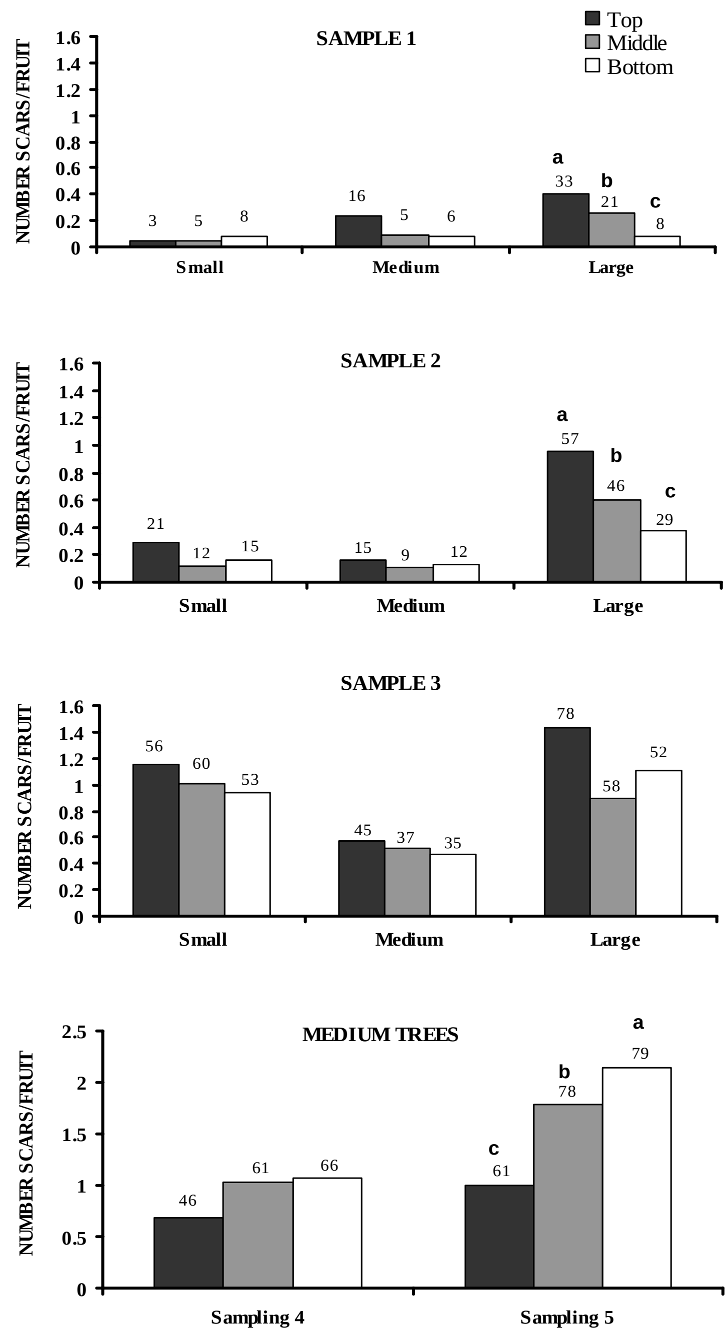

Figure 2. Distribution of the number of PC oviposition scars on fruit of small, medium and large trees according to branch level. Numbers above bars represent the mean percentage of fruit having at least one PC scar. Different letters above bars indicate significant differences among treatments at odds of 19:1. For sampling dates, see Table 1.

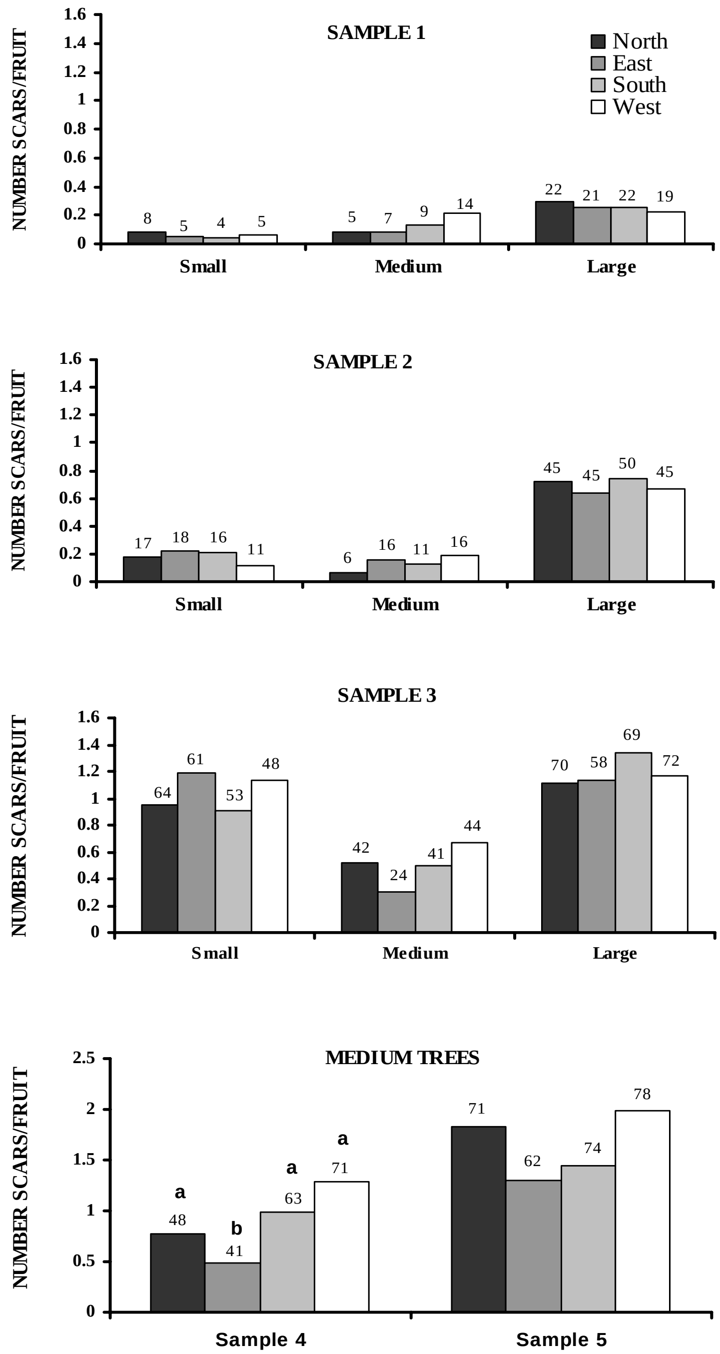

Figure 3. Distribution of PC oviposition scars according to branch orientation. Numbers above bars represent the mean percentage of fruit having at least one PC scar. Different letters above bars indicate significant differences among treatments at odds of 19:1. For sampling dates, see Table 1.

third sampling date (35-45%). Maximum percentage of fruit having one or more oviposition scars was reached on sampling date 5: 78 and 79% damaged fruit for the middle and bottom canopy levels, respectively. For large trees, oviposition scars were significantly greatest in the top level of tree canopies during all three sampling dates. Distribution of fruit having at least one PC scar also followed this pattern.

Branch orientation. Distribution of PC oviposition scars according to branch orientation for each tree size and sampling date is depicted in Figure 3. No significant differences in numbers of scars were found among branches oriented North, East, South and West on the first three sampling dates. Nor were there any obvious numerical trends. Across sampling dates 3, 4, and 5 for medium trees, however, fruit injury was consistently least on branches oriented East and greatest on branches pointing West. Percentages of fruit showing injury followed this same pattern.

Branch zone. For small trees, branches were not subdivided into exterior or interior zones. For medium trees, there were no significant differences in numbers of scars present on fruit located at exterior vs. interior zones of branches, regardless of branch level or sampling date (Figure 4). There was, however, a consistent numerical trend across all sampling dates (for both numbers of scars and percent fruit injured) toward greater PC damage on exterior than interior fruit at tree tops. There was no such consistent trend across sampling dates in the case of middles or bottoms. For large trees, for the first sampling date, scars were distributed similarly between interior and exterior zones of branches regardless of branch level (Figure 5). However, for sampling dates 2 and 3, infestation was significantly greater at the exterior zone of branches when branches were located in the top part of the tree. No significant differences in infestation levels were found between exterior vs. interior zones of branches located in the middle part of the tree canopy. For branches at the bottom part of the canopy, there was a notable numeri-

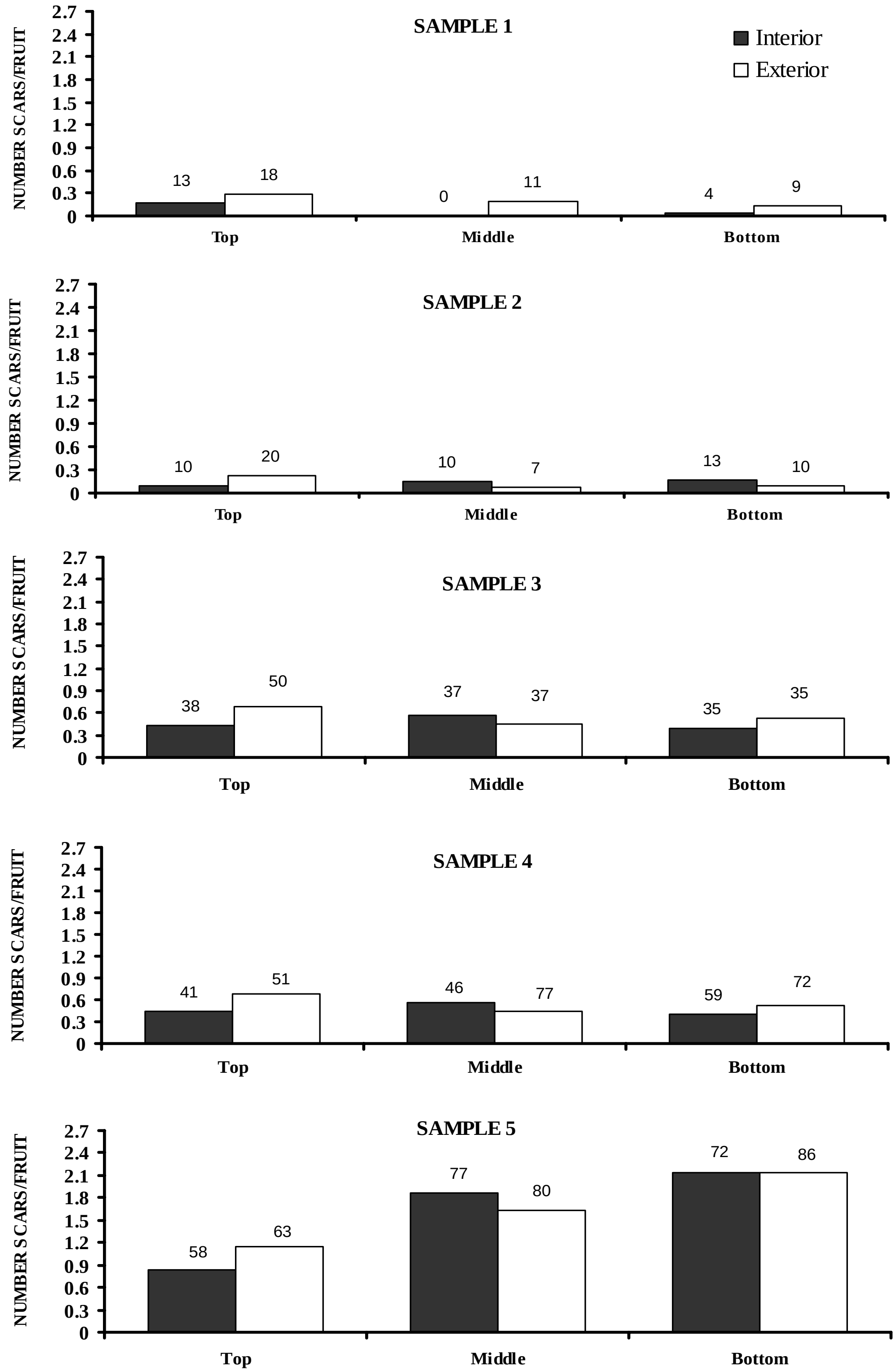

Figure 4. Distribution of PC oviposition scars on fruit located in external vs. internal zones of branches of medium trees. Numbers above bars represent the mean percentage of fruit having at least one PC scar. For sampling dates, see Table 1.

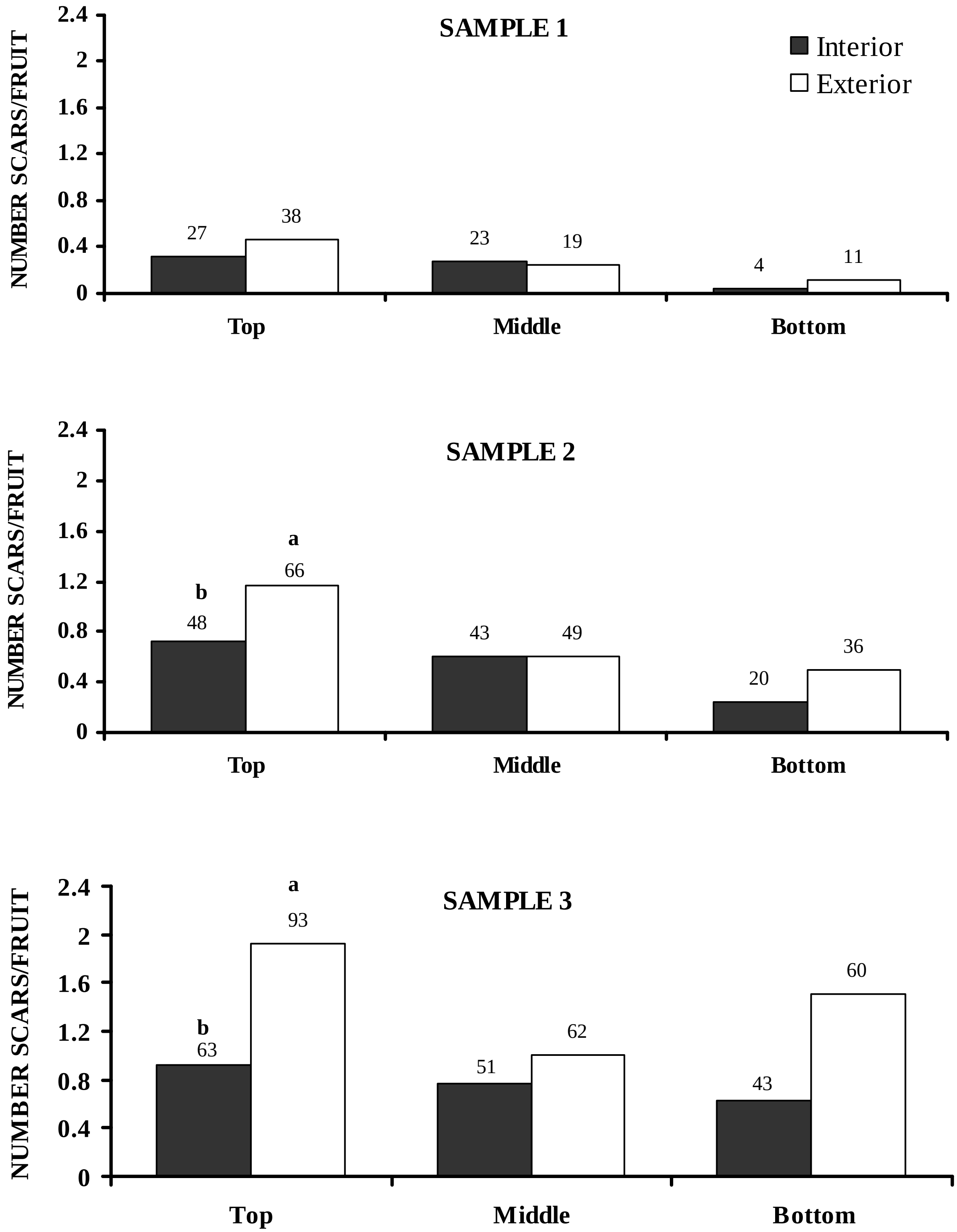

Figure 5. Distribution of PC oviposition scars on fruit located in external vs. internal zones of branches of large trees. Numbers above bars represent the mean percentage of fruit having at least one PC scar. Different letters above bars indicate significant differences among treatments at odds of 19:1. For sampling dates, see Table 1.

cal trend toward successively greater PC damage on exterior compared with interior zones as the season progressed (Figure 5).

Conclusions

Results suggest that PC infestation patterns vary according to tree size and sampling date, which is directly related to phenological stage of fruit development. With respect to the vertical plane of tree branches, results for large trees suggest greater damage (expressed as numbers of scars and percentages of injured fruit) at the tree top on all sampling dates, coinciding with previous reports of other researchers who found that PC scars in scout (Granny Smith) apples were detected only in the upper halves of large (McIntosh and Cortland) trees. For medium trees, the latter was true during the first sampling date, although differences were not significant. Our findings of a rather uniform infestation pattern among sectors of small trees does not concord with a report by Chouinard and collaborators (1994), who showed that in Quebec, PC oviposition scars were most abundant at the middle-level of small apple trees.

With respect to orientation of branches of small and large trees, our findings are in agreement with those of Le Blanc and collaborators (1984), who found no differences in oviposition scar frequencies according to the four cardinal points of the compass. For branches of medium trees during samplings 4 and 5, oviposition scars were most abundant on the West side of tree crowns. This location corresponds to the area where substantially more PC adults were found present at sunset (time of day when most oviposition activities occur), as confirmed by branch tapping performed on medium-sized trees on different days.

Determination of PC infestation patterns on exterior vs. interior zones of tree branches is an aspect that has not been evaluated heretofore. In general, no significant differences in PC damage were found for external vs. internal zones of branches of medium or large trees. However, as the season progressed, external zones of branches located at tops of both medium and large trees seemed to be the most prone to PC injury.

We used two indicators of PC injury because total numbers of PC scars may not correlate directly with numbers of fruit injured given that multiple wounds on a single fruit may be inflicted by either a single PC or multiple PCs. For the most part, these indicators were consistent with each other in our study. Our next step will be to determine if there is a correlation between fruit damage and numbers of PC adults captured by branch-mimicking black cylinder traps placed in different tree sectors. This will allow us to determine the best trap position within host tree canopies for the capture of PCs.

We conclude that damage to fruit by PCs is more likely to occur at the tops of large (and possibly medium) trees, particularly early in the season, with no influence of branch orientation. As the season progresses, external zones of branches located at tree tops become more prone to attack by PC than do internal zones of branches.

Acknowledgments.

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