Emergence of Root-feeding Weevils (Coleoptera: Curculionidae) in Central Georgia Peach Orchards[1]

Ted E. Cottrell[2] and Dan L. Horton[3]

United States Department of Agriculture, Agricultural Research Service
Southeastern Fruit and Tree Nut Research Laboratory
21 Dunbar Road, Byron, Georgia 31008 USA

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Abstract Injury to peach, *Prunus persicae* (L.) Batsch, roots is common by several plant pathogen species and by larvae of the peachtree borer, *Synanthedon exitiosa* Say (Lepidoptera: Sesiidae). External feeding injury to peach roots was observed that was not consistent with *S. exitiosa* injury but was suspected to be caused by the larvae of root-feeding weevil species (Coleoptera: Curculionidae). Thus, we used conical emergence traps for 3 yr to sample in unsprayed peach orchards (within the dripline of trees and at missing tree sites) to monitor for root-feeding weevils. Fuller rose beetle, *Naupactus cervinus* (Boheman), whitefringed beetles, *Naupactus* spp., and the twobanded Japanese weevil, *Callirhopalus bifasciatus* (Roelofs), (Coleoptera: Curculionidae) were captured at significantly higher numbers within the dripline of the tree than at missing tree sites. Adult *N. cervinus* emerged from soil year around; whereas, the other 2 species had seasonal emergence. In commercial peach orchards comprised of cultivars with early, mid, and late-season fruit ripening dates, *N. cervinus* was more abundant than other species. The later a cultivar ripens, the higher the number of insecticide applications it receives; however, we did not detect a difference in *N. cervinus* emergence between the cultivars. In another sprayed orchard, *N. cervinus* was again more common than other curculionid species captured. Damage ratings (0 - 5; none to heavy, respectively) on roots revealed a mean rating of 2.79 ± 0.12. Year-long emergence of *N. cervinus* is likely why it persisted in sprayed orchards. Modification of existing pest management programs will be needed to manage *N. cervinus* attacking peach roots.

Key words *Naupactus*, *Callirhopalus*, *Sitona*, *Sphenophorus*, *Prunus*, root-feeding

Economic injury commonly results from numerous pests attacking the roots of peach, *Prunus persicae* (L.) Batsch (Rosaceae). These pests include various plant pathogenic nematodes (Nyczepir and Esmenjaud 2008), fungi (Schnabel and Miller 2005, Cox et al. 2005) and *Agrobacterium tumefaciens* (Scherm 2005). Due to the importance of the first 2 pest groups, peach rootstock breeding programs have focused most attention toward developing rootstocks less susceptible to them. The only root-feeding insect pest for which control action is taken is the peachtree borer, *Synanthedon exitiosa* Say (Lepidoptera: Sesiidae) (Horton and Johnson 2005). Across most of the southeastern U.S., *S. exitiosa* is univoltine, thus facilitating control with a single, late-season application of an insecticide to peach trunks where most eggs are laid (Horton et al. 2006, 2008). However, recent examinations of roots reveal that

[1]Received 28 September 2012; accepted for publication 10 December 2012.
[2]Address inquiries (email: ted.cottrell@ars.usda.gov).
[3]University of Georgia, Department of Entomology, 463 Biological Sciences Bldg., Athens, GA 30602.

S. exitiosa is not the only root-feeding insect to attack peach and cause substantial root injury.

Observations of peach roots reveal that larval *S. exitiosa* feed within galleries on the inner bark and cambium and extrude frass from an external opening at a point along the gallery (Johnson et al. 2005). In contrast, another type of feeding injury was easily discernible from *S. exitiosa* injury to roots. This feeding injury occurred externally, not internally, on roots. In addition, it occurred on smaller-diameter roots than *S. exitiosa* typically uses. This external feeding injury was consistent with that expected from the larvae of root-feeding weevil species (Coleoptera: Curculionidae) (Johnson and Lyon 1988).

It is not known if root-feeding weevil injury to peach has generally been overlooked or if changes in pesticide use on peach have resulted in increased damage. For example, during the 1990s, damage to southeastern U.S. peach orchards by the lesser peachtree borer, *Synanthedon pictipes* (Grote & Robinson), increased dramatically as a likely result of insecticide regulatory changes during that time (Horton et al. 2000). San Jose scale, *Quadraspidiotus perniciosus* (Comstock) (Hemiptera: Diaspididae), and white peach scale, *Pseudaulacaspis pentagona* (Targioni-Tozzett) (Hemiptera: Diaspididae), also became problematic during that time and likely for the same reason (Horton et al. 2000). This recently observed root injury is likely to be important regarding orchard longevity and profitability, especially given the importance of root-damaging nematodes (Nyczepir and Esmenjaud 2008), fungi (Adaskaveg et al. 2008) and the peachtree borer (Horton and Johnson 2005) to overall tree health.

The objective of this study was to capture the adult stage of larval insects likely feeding on peach roots. This was done by capturing insects emerging from soil within, or outside of, the dripline of peach trees. Insects were monitored for 3 yr in research orchards that were not treated with insecticides and for 1 season in commercial plantings that received insecticide applications. In another research orchard, we monitored insect emergence and also collected roots and rated them for external feeding injury.

Materials and Methods

Three-yr emergence study. Conical emergence traps were monitored from 30 August 2006 - 10 September 2009 in 2, mixed-cultivar peach orchards at the USDA, ARS, Southeastern Fruit and Tree Nut Research Laboratory at Byron, GA. Spacing within and between trees in these orchards was 5.5×6.1 m, respectively. Traps were constructed from galvanized screen wire and each covered approx. 0.65 m^2 of soil surface (Polles and Payne 1972). Tree fertilization and weed control in these orchards was maintained similarly per guidelines for southeastern U.S. peach production (Horton et al. 2006). These trees were not treated with insecticides or fungicides during this time. Generally, traps were sampled once per wk during winter months but $3 \times$ per wk otherwise. Increased sampling during spring, summer and fall was to prevent possible removal of trapped insects by foraging red imported fire ants, *Solenopsis invicta* Buren (Hymenoptera: Formicidae). At the beginning of the study, 20 traps were placed within the dripline of peach trees (e.g., 10 traps per orchard; 1 trap per tree) where a higher concentration of roots was expected. Another 20 traps (10 traps per orchard) were also placed within the peach row, but only at sites where trees had died and been removed; very few, if any, peach roots were expected here. Placing traps at missing tree sites within the row, as opposed to between rows (i.e., in row middles), prevented traps from being damaged by machinery (e.g., tractors and mowers) operating in orchards. On 11 April 2007, 40 additional traps were placed in these orchards, as previously described, for monitoring; 20 underneath trees and 20 at missing tree sites. Between 22 May 2008 and 6 Jun 2008, all traps adjacent to peach trees were moved to the opposite side of the peach tree and traps at missing tree locations were moved to an immediately adjacent site that was not previously covered by the trap. Movement of traps was done as a precaution against traps affecting future capture of weevils by preventing eggs or larvae from reaching the soil underneath a trap.

For weevil genera, or species, with consistent trap captures, we used the Chi-square Goodness of Fit test to infer whether observed frequencies of weevils sampled from traps at both locations (i.e., within the dripline of trees and from missing tree sites) conformed to a theoretical frequency of 1:1 (Zar 1999). For these analyses, the cumulative numbers of weevils (by genus or species) for each trap location (within the dripline or at missing tree sites) were analyzed using a Chi-square analysis (Zar 1999).

Commercial orchard sampling. Eleven cone emergence traps were placed in each of 3 commercial peach orchards on 28 March 2007 and monitored 3 × per week until 19 November 2007. Spacing within and between trees in these orchards was 6.1 × 6.1 m, and the size of each orchard was at least 4 ha. Each orchard was comprised of a single peach cultivar with fruit that ripened early (Sunbrite), mid

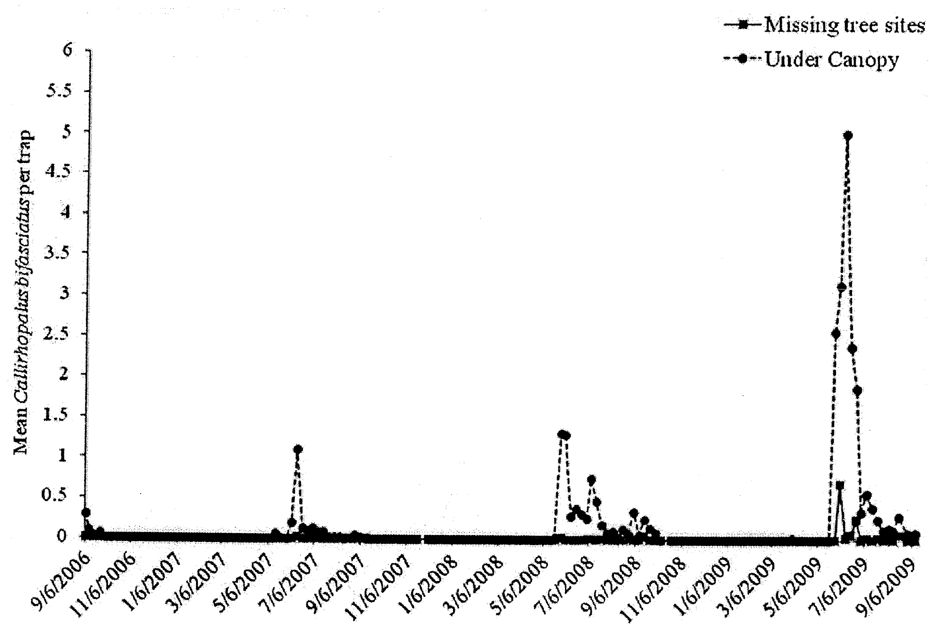

Fig. 1. Capture of adult twobanded Japanese weevil, *Callirhopalus bifasciatus*, in conical emergence traps in unsprayed, central Georgia peach orchards from September 2006 to September 2009. Traps were placed on the orchard floor within the dripline of peach trees or at missing tree sites in peach rows.

(Harvester), or late season (Sunprince). Cultivars with different fruit ripening dates typically receive the same (or at least similar) insecticides (i.e., phosmet and various pyrethroids), primarily targeting fruit-attacking pests, but a different number of applications depending upon harvest date. These cultivars were chosen because duration of insecticide applications could affect abundance of root-feeding weevils. Approximate fruit ripening dates of these early, mid and late cultivars are the last week of May, last week of June and midJuly, respectively (Okie 1998). Within each cultivar, 8 traps were placed within the dripline underneath the tree canopy and 3 traps were placed at missing tree sites. Eleven additional traps were placed in each orchard again on 1 June and again on 30 July 2007. On each date, 8 traps were placed underneath trees within the dripline and 3 traps were placed at missing tree sites in rows. Orchard management followed similarly per Horton et al. (2006). The nonparametric Kruskal-Wallis test was used to compare trap capture of adult *N. cervinus* from within the dripline of Sunbrite, Harvester and Sunprince cultivars (Zar 1999, SAS Institute 2012).

Root damage rating. Thirty-six conical emergence traps were placed, 1 per tree, within the dripline of trees in an 8-yr-old peach cultivar selection trial (USDA selection 85P322). Spacing within and between trees in this orchard was 6.1 × 6.1 m. This orchard received in-season pesticide applications (mainly phosmet) for fruit-attacking pests (Horton et al. 2006). Traps were placed in the orchard on 5 September 2008 and monitored once per week until 14 October 2008. During late October 2008, the orchard was pushed up which allowed for collection of roots from each tree associated

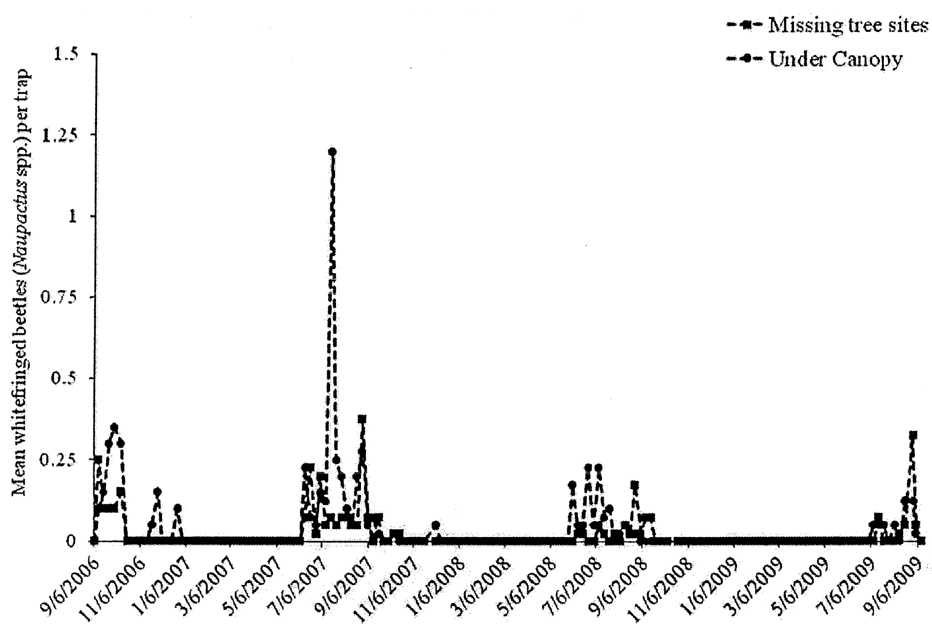

Fig. 2. Capture of adult whitefringed beetle, *Naupactus* spp, in conical emergence traps in unsprayed, central Georgia peach orchards from September 2006 to September 2009. Traps were placed on the orchard floor within the dripline of peach trees or at missing tree sites in peach rows.

with a conical emergence trap. Eight root samples of similar length (36.7 ± 0.4 cm) were randomly cut from each tree. For each root, the diameter was measured and the surface feeding injury was rated: 0 = no damage; 1 = light damage; 2 = light to moderate damage; 3 = moderate damage; 4 = moderate to heavy damage; 5 = heavy damage. Weevil species collected from traps were identified and the mean number of *N. cervinus* adults per trap was determined. Additionally, the mean diameter of roots sampled was determined as was the mean injury rating.

Results

Three-yr emergence study. Adult weevil species (Coleoptera: Curculionidae) collected from conical emergence traps in peach orchards during this study included: plum curculio, *Conotrachelus nenuphar* (Herbst); pea leaf weevil, *Sitona lineatus* (L.); vegetable weevil, *Listroderes difficilis* Germar; billbugs, *Sphenophorus* spp.; *Cercopeus strigicollis* Sleeper; twobanded Japanese weevil, *Callirhopalus bifasciatus* (Roelofs); alfalfa weevil, *Hypera postica* (Gyllenhal); whitefringed beetles, *Naupactus* spp., and Fuller rose beetle, *N. cervinus* Boheman. It should be noted that not all species were captured in numbers sufficient for statistical analysis.

Significantly more *N. cervinus* ($\chi^2 = 2275.64$, df = 1, $P < 0.001$), *C. bifasciatus* ($\chi^2 = 1419.5$, df = 1, $P < 0.001$), *Naupactus* spp. ($\chi^2 = 14.58$, df = 1, $P < 0.001$) and *S. lineatus* ($\chi^2 = 1789.24$, df = 1, $P < 0.001$) were captured over the 3 yrs in the traps placed within the dripline of peach trees than in traps placed at missing tree sites. In contrast, significantly more *Sphenophorus* spp. were captured in traps placed at missing

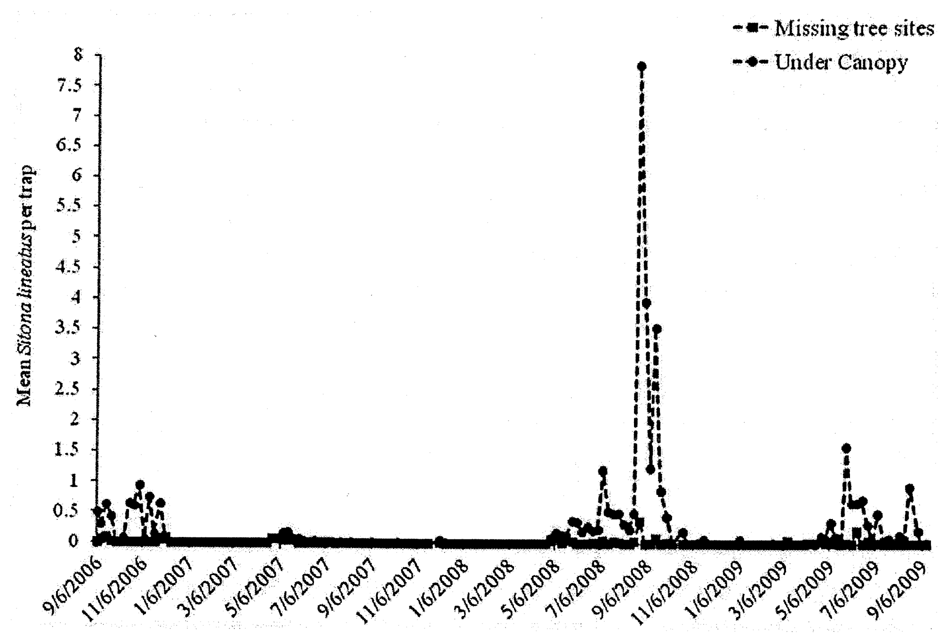

Fig. 3. Capture of adult pea leaf weevil, *Sitona lineatus*, in conical emergence traps in unsprayed, central Georgia peach orchards from September 2006 to September 2009. Traps were placed on the orchard floor within the dripline of peach trees or at missing tree sites in peach rows.

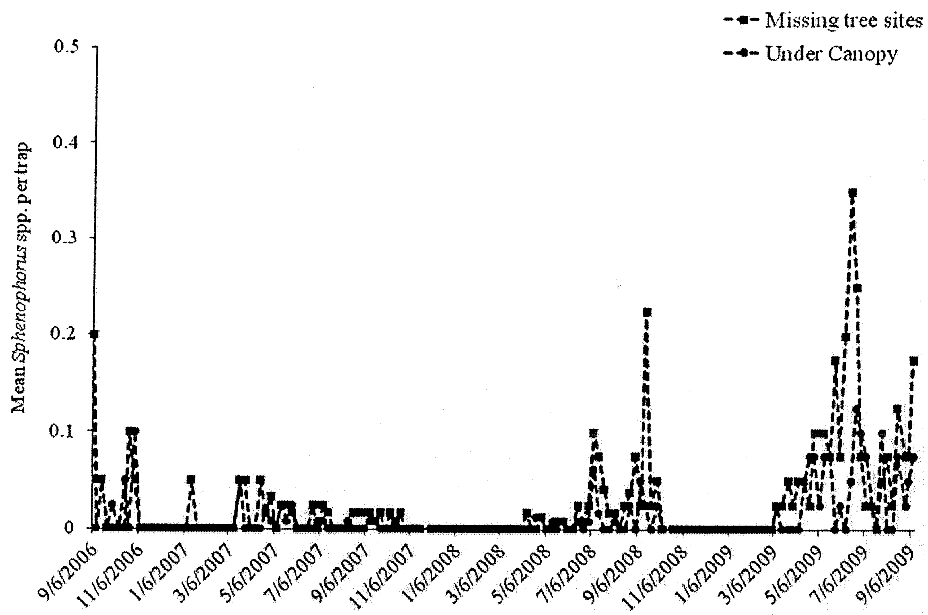

Fig. 4. Capture of adult billbugs, *Sphenophorus* spp., in conical emergence traps in unsprayed, central Georgia peach orchards from September 2006 to September 2009. Traps were placed on the orchard floor within the dripline of peach trees or at missing tree sites in peach rows.

tree sites ($\chi^2 = 46.42$, df = 1, $P < 0.001$). Adult emergence of most species occurred predominantly during the growing season (Fig. 1 - 4). However, emergence of *N. cervinus* adults occurred throughout the year, even during late fall and winter when peach trees were defoliated (Fig. 5).

Commercial orchard sampling. The abundance of adult weevil species captured within the dripline of trees in commercially managed peach orchards was different compared with the unsprayed, research orchards. Here, 90% of captured weevils were *N. cervinus* and 8.7% were *N. peregrines*. Very low numbers of other weevil species were captured and, in fact, only 1 adult *C. bifasciatus* was captured in these commercial orchards during this study.

When emergence traps, placed within the dripline of peach trees, were examined from late March through midNovember 2007, a significant difference was not detected in capture of adult *N. cervinus* between early, mid and late-ripening cultivars (Kruskal-Wallis $\chi^2 = 2.71$, df = 2, $P = 0.2585$) (Fig. 6). During this sampling interval, 2 emergence peaks were noted for all cultivars during early June and late August (Fig. 7). Adult *N. cervinus* captured at missing trees sites represented only 2.9% of the total captured from all orchards. This low percentage could be the result of 3 possibilities: (1) few peach roots were available under cone emergence traps at missing tree sites, (2) most peach roots extending that distance were not suitable for larval development, or (3) larvae did not move that far from sites where females laid eggs.

Root damage rating. As in the commercial orchards, the vast majority of adult weevils (98.2%) captured in this orchard were *N. cervinus*. Cumulative numbers of adult *N. cervinus* captured in cone emergence traps within the dripline of trees were

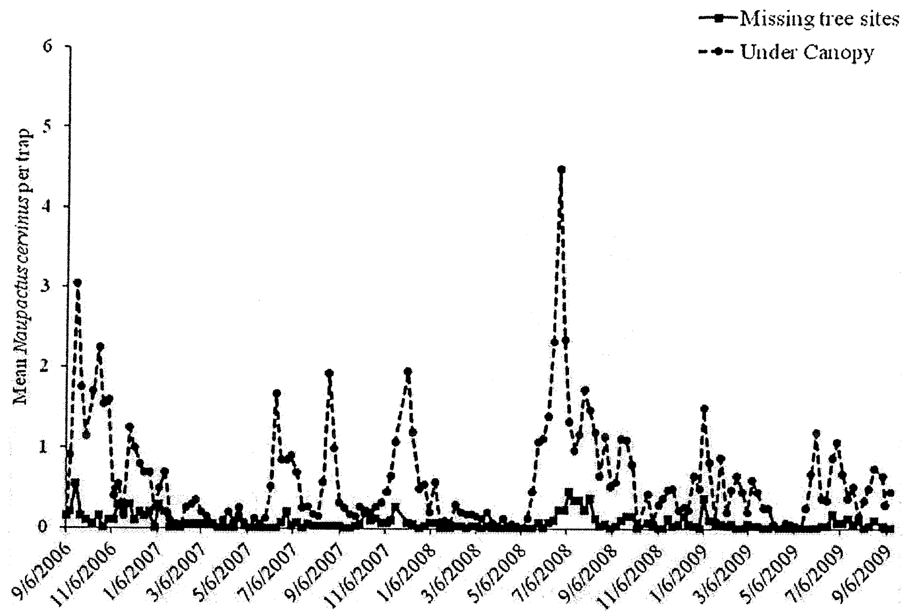

Fig. 5. Capture of adult Fuller rose beetle, *Naupactus cervinus*, in conical emergence traps in unsprayed, central Georgia peach orchards from September 2006 to September 2009. Traps were placed on the orchard floor within the dripline of peach trees or at missing tree sites in peach rows.

variable by tree and ranged from 0 - 128 with an average of 17.97 ± 5.14 per trap. Although some individual roots were not observed to have external feeding injury, all sampled trees had external feeding injury to roots. Using a rating scale from 0 - 5, the mean (±SE) damage rating of roots was 2.79 ± 0.12. Average diameter of roots collected and rated for feeding injury was 1.63 ± 0.08 cm.

Discussion

We did not directly document feeding by any insect species on peach roots. However, based upon the literature and the close association of the adult weevils emerging near peach trees, it is likely that larvae of Fuller rose beetle, whitefringed beetles and the twobanded Japanese weevil, all being polyphagous, feed on peach roots (Johnson and Lyon 1988). Those authors also state that larvae of the Fuller rose beetle 'feed on both feeder and suberized roots' and that peach is one of the more common hosts of adult Fuller rose beetle. Similarly, those same authors state that whitefringed beetle larvae feed on the 'soft suberized bark of roots' of *Prunus* and other woody host plants. Smith (1955) reported the twobanded Japanese weevil feeding on numerous host plant species including rose (i.e., a member of the Rosaceae as is peach). The twobanded Japanese weevil was even shown to have higher fecundity when adults fed on foliage of *Rosa multiflora* Thunb. (Rosaceae) compared with

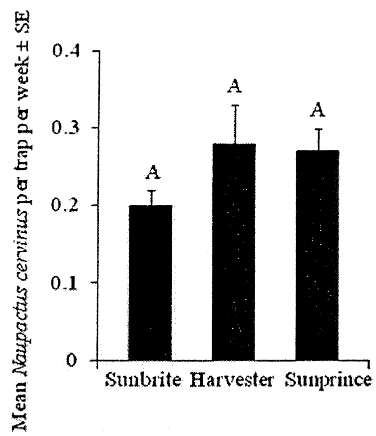

Fig. 6. Mean number of adult Fuller rose beetle, *Naupactus cervinus*, captured per trap each week from 28 March to 19 November 2007 in early (Sunbrite), mid (Harvester) and late (Sunprince) ripening peach cultivars; 'Sunbrite', 'Harvester' and 'Sunprince', respectively. Weevil emergence was detected using conical emergence traps placed on the orchard floor within the dripline of peach trees. All orchards were under commercial management and received recommended in-season insecticide applications.

other nonrosaceous plants (Maier 1983). It is interesting that much of the older literature concerning these insects attacking Rosaceae and *Prunus* is directed toward foliar feeding by adults whereas ignoring the host plants that larvae may use and the injury they cause to those plants.

Kovach (1986) reported emergence of adult Fuller rose beetle in cone emergence traps near the base and at the dripline of peach trees. Similarly as in the current study, almost all adults emerged within the dripline of peach with very low emergence outside of this area (i.e., in sod middles between peach rows). In contrast with the current study, Kovach (1986) sampled for Fuller rose beetle from 1 September through 11 November of the same year; whereas, we consecutively sampled emergence in one study for 3 years. During our sampling interval, adult Fuller rose beetle was collected during each month of the year. The duration of adult emergence far exceeds usage of in-season insecticide treatments for other direct and indirect peach pests. This could account for the observation that Fuller rose beetle, but not the other species with in-season emergence patterns, was so dominant in insecticide-treated peach orchards.

Even though more adults of the pea leaf weevil were captured within the drip line of peach trees, the literature clearly indicates it feeds mainly on legumes, not woody plants (Bright 1994, Vankosky et al. 2011). The main legumes in these peach orchards were clovers and vetch. Both can be present from the fall through spring when herbicide strips in peach orchards are not as rigorously maintained. However, other than casual observations on the occurrence of clover and vetch, we did not actively survey for other possible host plants at these locations. Billbugs are mostly associated with grass species (Triplehorn and Johnson 2005) and were mostly collected, as would have been expected, from traps at missing tree sites where grass was more abundant, (i.e., herbicide strips are not perfect). The

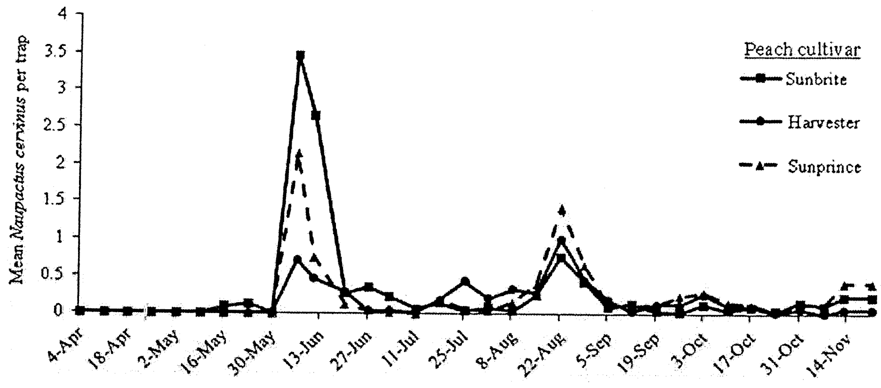

Fig. 7. Seasonal emergence of adult Fuller rose beetle, *Naupactus cervinus*, in commercially managed peach orchards comprised of 'Sunbrite', 'Harvester',and 'Sunprince' cultivars that have early, mid and late fruit ripening dates, respectively. Emergence was sampled from 28 March to 19 November 2007. Traps were placed on the orchard floor within the dripline of peach trees.

literature leads us to surmise that neither the pea leaf weevil nor billbugs were actively attacking peach roots. In contrast, it is likely that larvae of Fuller rose beetle (and possibly larvae of whitefringed beetles and twobanded Japanese weevils) can use weedy plant species for survival, even if they are not preferred hosts (Logan et al. 2008).

Fuller rose beetle, whitefringed beetles and twobanded Japanese weevils are introduced species in North America (Maier 1983, Johnson and Lyon 1988). All species are flightless, parthenogenetic and polyphagous (Smith 1955; Woodruff and Bullock 1979; Staines and Staines 1988, Johnson and Lyon 1988, Wheeler and Boyd 2005). Dispersal of these flightless insects is suspected with movement of plant material and accompanying soil (Johnson and Lyon 1988). Additionally, it is highly conceivable that adult weevils would drop onto farm machinery, i.e., mowers, operating in orchards, nurseries or even along hedgerows and thus be moved considerable distances. Adults of all species feed on foliage and larvae can feed on the roots of those same plants.

Management of whitefringed beetles and the twobanded Japanese weevil is likely achieved inadvertently in peach orchards with in-season insecticide treatments, as seen in the commercial orchards sampled in this study. However, as also seen in the commercial orchards sampled here, Fuller rose beetle may still be problematic with just these in-season treatments and still require one or more additional treatments; likely a very early and a late-season application. At this time, research is needed to ascertain feeding damage by these species, especially Fuller rose beetle, and the extent of its economic injury to peach.

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