Overwintering of *Stethorus punctum punctum* (Coleoptera: Coccinellidae) in Apple Orchard Ground Cover

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ABSTRACT Overwintering of adult *Stethorus punctum punctum* (LeConte) was investigated in apple orchards in south-central Pennsylvania. A separation technique was developed to remove adults from soil samples. Density of overwintering adults in the autumn was greatest in the area around the trunks of the apple trees, but because of the relatively small area of the ground cover in the trunk zone, more adults were located in the remainder of the herbicide strip and in the border between the herbicide strip and drive row. In the spring, however, >70% of the adults were located in the trunk zone. Adults were associated with fallen leaves and apple root suckers. Density of adults in orchard ground cover peaked in midautumn and declined to relatively low levels in the spring. Methods to conserve this predator while managing tufted apple bud moth, *Platynota idaeusalis* (Walker), are discussed.

KEY WORDS *Stethorus punctum punctum*, overwintering, apple, Coccinellidae, ground cover

Ladybird beetles in the genus *Stethorus* are obligate predators of tetranychid mites contributing to mite management in tree fruit in various parts of the world (Kapur 1948). Conservation of *S. punctum punctum* (LeConte) for control of the European red mite, *Panonychus ulmi* (Koch), and the twospotted spider mite, *Tetranychus urticae* Koch, is the cornerstone of the apple-integrated pest-management program in Pennsylvania and surrounding areas of the mid-Atlantic region (Asquith and Hull 1979). This program currently involves selectively timed applications of low rates of organophosphate and carbamate insecticides, acaricides, and fungicides to control other major insect and disease pests (Anonymous 1996).

The major direct pest, tufted apple bud moth, *Platynota idaeusalis* (Walker), has developed resistance to the organophosphate insecticide azinphosmethyl with resulting control failures (Knight and Hull 1992). Because the carbamate/organophosphate insecticide mixtures used to control tufted apple bud moth threaten the successful IPM program, several alternative control tactics for tufted apple bud moth are being investigated. One tactic involves applying an insecticide to overwintering larvae of tufted apple bud moth in the orchard ground cover in the spring (Bode 1975, Knight and Hull 1988).

To be successful, management tactics directed to the ground cover must control tufted apple bud moth without causing excessive mortality of *S. punctum*, which also overwinters in the orchard ground cover. This predator belongs to a group of coccinellids that do not move to a new habitat for hibernation, but overwinter in the orchard and surrounding refugia singly or in small groups under tree bark, litter, or in the upper layers of the soil (Hodek 1973). However, little is known on the distribution of *S. p. punctum* in the various overwintering habitats in the orchard ground cover and surrounding refugia. Colburn and Asquith (1971) sampled overwintered *S. p. punctum* in apple orchards in May, but sampled only fallen leaves within 1.5-m apple trunks. They found the adult distribution skewed toward the trunks where leaves were present. The purpose of this experiment was to determine the spatial and temporal distribution of *S. p. punctum* adults in all available ground cover habitats in apple orchards and surrounding refugia so that management tactics developed for tufted apple bud moth larvae in the ground cover will not interfere with the mite predator.

Materials and Methods

Sampling Procedure. A technique was developed to separate overwintering *S. p. punctum* adults from soil samples. Samples of organic matter consisting of the O1 layer of loose leaves and undecomposed organic debris and the O2 layer of matted and decomposed organic material (Foth 1978) from an area of 0.1 m² within 1 m from the trunk of an apple tree were taken under each of 8 trees in February 1991. The organic matter was sifted through a 6-mm screen. The fine (<6 mm) and coarse fractions (>6 mm) were each placed in clear plastic containers (34 by 24 by 8 cm) (Freezette food saver, Max Klein, Baraboo, WI) with 2
screened ventilation openings in the lid, and held in the laboratory with natural lighting. Adults were removed each morning for 13 d from resting places on the inside of the separator box lids. The samples were visually searched for remaining adults on day 13.

A further separation efficacy procedure was conducted in December 1992. *S. p. punctum* adults were separated from orchard soil samples as described above. Eighteen adults removed from samples after 1 or 2 d were buried in a sample of sifted soil with no *S. p. punctum*. Efficacy was rated as the number of adults collected again over the following 10 d.

Two samples of soil strata were taken 7 and 9 March 1991 from the herbicide strip of an apple orchard to determine the location of *S. p. punctum* overwintering sites. Samples were taken using a 0.1-m² frame within 1 m of the trunk at sites with known high adult densities. The 1st fraction removed was primarily leaf litter (O1 and O2). Next, a whisk broom was used to collect the remaining organic matter (O2) from the soil surface. Finally, 0-1-cm and 1-2-cm soil fractions (Ap, plow layer) were dug with a spade. Samples were brought to the laboratory and sifted through 6-mm screen. The material >6 mm was discarded and the sifted fractions were placed in separator boxes. Adults were removed daily for 10 d.

**Orchard Survey.** Distribution of *S. p. punctum* adults was determined in the ground cover of four representative 'Yorking' apple orchards in Adams County, Pennsylvania, between autumn 1991 and summer 1993. The trees were 20–30 yr old and planted on standard or semidwarfing rootstocks at 190–303 trees per hectare. The understory of each orchard was stratified into 4 zones from which samples were taken (Felland et al. 1996). The trunk zone included a 0.6-m radius out from the trunk, the remainder of the herbicide strip extending from 1.5-2.0 m from the trunk, and the border zone included a 0.6-m radius out from the trunk. The refugia was calculated only on a per-square-meter basis. Host biomass remaining organic matter and soil were sifted through 6 mm hardware cloth and the adults were removed with the above separation procedure. On most sampling dates the intact fallen leaves of the O1 layer were examined in situ to determine location of adults within the organic matter and the remaining O2 and Ap sample was placed in a plastic bag and sifted in the laboratory. In the December 1991 and April 1992 samples the entire sample was bagged and examined in the laboratory without the location of adults being differentiated as to soil layer. In the October samples both years the number of adults per infested leaf was recorded.

The percentage of the ground cover with fallen leaves, apple root suckers, broadleaf weeds, and grasses was visually estimated for each sample. The percentages were based on the amount of soil surface covered with the particular host. Host biomass was not measured, except in the case of fallen leaves, which were dried to a constant weight and weighed.

Density of *S. p. punctum* adults was calculated in three ways. First, the number per square meter was determined for each ground cover zone. Second, because the 4 zones were not uniform in size, the same data were converted to percentage per zone. This percentage was calculated by using the actual areas of each zone on an orchard-by-orchard basis. And 3rd, the number per square meter for the orchard as a whole was estimated. Density in the refugia was calculated only on a per-square-meter basis because sampling was not extensive enough to quantify the absolute density in the refugia relative to the orchard.

Analyses were conducted independently for the autumn, spring, and summer collections. The 3 autumn samples each year were pooled and only the April sample was included in the spring samples because no adults were recovered in May. The analyses were split plot with zone as whole plot,
or...
Table 1. Mean ± SEM number of S. p. punctum adults per square meter in 4 zones of ground cover of apple orchards and in refugia during 3 seasons, Adams County, Pennsylvania, 1991–1993

<table>
<thead>
<tr>
<th>Zone</th>
<th>Autumn</th>
<th>Spring</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk</td>
<td>28.27 ± 5.50a</td>
<td>3.64 ± 1.65a</td>
<td>0.00 ± 0.00a</td>
</tr>
<tr>
<td>Herbicide strip</td>
<td>4.13 ± 0.94b</td>
<td>0.08 ± 0.08b</td>
<td>0.00 ± 0.00a</td>
</tr>
<tr>
<td>Border</td>
<td>2.81 ± 0.84cd</td>
<td>0.16 ± 0.11b</td>
<td>0.06 ± 0.06a</td>
</tr>
<tr>
<td>Drive row</td>
<td>1.23 ± 0.48d</td>
<td>0.00 ± 0.00b</td>
<td>0.00 ± 0.00a</td>
</tr>
<tr>
<td>Refugia</td>
<td>1.00 ± 0.52</td>
<td>0.83 ± 0.47</td>
<td>0.00 ± 0.00</td>
</tr>
</tbody>
</table>

Means within columns followed by the same letter are not significantly different (Fisher protected LSD, P > 0.05).

Table 2. Percentage (± SEM) per zone of adult S. p. punctum in the apple orchard ground cover during 3 seasons, Adams County, Pennsylvania, 1991–1993

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Trunk</td>
<td>15.0 ± 4.7b</td>
<td>71.0 ± 18.6a</td>
<td>0.0</td>
</tr>
<tr>
<td>Herbicide strip</td>
<td>58.7 ± 11.9a</td>
<td>9.8 ± 9.8b</td>
<td>0.0</td>
</tr>
<tr>
<td>Border</td>
<td>20.8 ± 6.7b</td>
<td>19.3 ± 19.3b</td>
<td>100.0</td>
</tr>
<tr>
<td>Drive row</td>
<td>5.2 ± 4.3b</td>
<td>0.0 ± 0.0b</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Means within columns followed by the same letter are not significantly different (Fisher protected LSD, P > 0.05). Values for individual orchards were calculated by multiplying density in each zone by relative area of each zone, dividing the total per zone by the total per all zones, and multiplying by 100%.

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Table 1. Mean ± SEM number of S. p. punctum adults per square meter in 4 zones of ground cover of apple orchards and in refugia during 3 seasons, Adams County, Pennsylvania, 1991–1993

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and the spring samples. Adult density in refugia was not as high as the trunk zone, but tended to remain constant between the autumn and spring samples.

The distribution of adults among the 4 ground cover zones changed between the autumn and spring samples (Table 2). The highest percentage of adults in the autumn were found in the herbicide strip, whereas in the spring most adults were found in the trunk zone. Colburn and Asquith (1971) found 50 and 80%, respectively, of adults within 0.3 and 1.0 m of the trunks in spring samples of leaf litter when the litter was against the tree. Readshaw (1971) also observed Steathorus spp. concentrated in leaf litter and herbage around the base of apple trees.

The leaves in the trunk zone may be caught in the root suckers and offer a more stable overwintering site for the adults than in the other zones. The leaves in the other orchard zones may be raked into the drive rows during the pruning operation. Alternatively, some active movement of adults toward the trunks may occur during warm periods in the early spring. Asquith and Hull (1979) reported adults feeding on mites and mite eggs on the trunks during warm sunny days before moving into the trees.

Multiple regressions of variables of ground cover habitat within sample area and density of S. p. punctum adults had low coefficient correlations in most instances indicating little multicollinearity between variables. High densities of adults were positively correlated with presence of fallen leaves and apple root suckers and with fallen leaves alone in the autumn (Table 3). Although apple root suckers had a high beta value, this variable was not significant (P > 0.05). In the spring, when most of the suckers had been pruned, only the presence of fallen leaves was significant.

Low density of adults in the April samples both years suggests relatively high overwintering mortality. Emergence from the overwintering sites was <15% when these samples were taken (Felland et al. 1995). In contrast to the orchard, density remained relatively high in the refugia, which tended to have a thicker layer of organic matter. Putman (1955) caged adults of S. punctillum, which overwinter in similar habitats as S. p. punctum, on dead leaves, soil, and sod and reported only 20.0–27.5% overwintering survival and found no survival of adults overwintering on an apple limb. Little snow cover occurred to modify temperature in the overwintering sites. During the winter of 1991–1992 snow cover averaged 4.7 cm over a total of 13 d. In the winter of 1992–1993 snow cover averaged 1.7 cm for 3 d until 13 February, after which an average of 19.3 cm remained through 27 March.

The cues used by adults for entering overwintering sites are not well understood. Adults may move to the base of the trees and remain in a favorable habitat of fallen leaves trapped among the apple root suckers. The highest density of adults for the area of the ground cover under an entire tree was 36.3/m². The maximum number in a single 0.1-m² sample was 31 adults in the trunk zone. Adults have been found aggregated with up to 12 in a single fallen leaf (C.M.F., unpublished data).

Whether this aggregation is a result of movement toward optimum habitat or of an aggregation pheromone is not known.

Little overlap occurs in the temporal and spatial distribution during the spring of overwintering adult S. p. punctum with that of larval tufted apple bud moth. The coccinellids leave overwintering sites several weeks before the tufted apple bud moth enters the pupal stage allowing a window of opportunity to manage the pest without disrupting the predator (Felland et al. 1995). Spatially, the coccinellids are concentrated around the trunks, whereas the tufted apple bud moth larvae tend to be most common in the herbicide strip and the border (Felland et al. 1996). Thus, habitat left undisturbed to increase overwintering of the coccinellid (e.g., leaves collected among root suckers) may not greatly increase the density of tufted apple
bud moth. Hibernal shelters have been used to conserve predators in other crops (Sengonca and Henze 1992).

Experimental studies should be conducted in which potential overwintering sites in the ground cover are manipulated. Pruning of root suckers and raking of leaves at different seasons could be investigated. The impact of rootstocks with little root sucker growth, which are preferred by growers, on S. punctum overwintering should also be examined.

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