# Overwintering Emergence and Trapping of Adult *Stethorus punctum punctum* (Coleoptera: Coccinellidae) in Pennsylvania Apple Orchards

C. M. FELLAND, D. J. BIDDINGER, AND L. A. HULL

Pennsylvania State University, Fruit Research Laboratory, Biglerville, PA 17307

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**ABSTRACT** Emergence of adult *Stethorus punctum punctum* (LeConte) from overwintering sites in apple orchards was examined for 3 yr in Adams County, Pennsylvania. Emergence during the spring in cages placed over overwintered individuals occurred between 100 and 300 degree-days (DD) when temperature units were accumulated beginning 1 March. Fifty percent emergence occured at 210 $DD_{5°C}$. Emergence was 2.3, 46.7, and 95.8% complete by the half inch green, pink, and the petal fall stages of 'Yorking' apple development, respectively. Most adults emerged on days of average, minimum, and maximum air temperatures of 15–20, 5–15, and 20–30°C, respectively. Temperatures in overwintering habitat were similar to ambient air temperature. Counts in the tree canopy were highly correlated with capture in the emergence cages in a warm year, but were too low to relate to capture in the other two cooler years. Capture of adults on yellow sticky boards was an efficient monitoring method; first capture occurred at 20–30% emergence. Yellow traps were more effective than white, and addition of ammonium carbonate did not significantly increase capture with yellow traps, but inhibited capture with white traps.

**KEY WORDS** *Stethorus punctum punctum*, overwintering emergence, trapping

COCCINELLID BEETLES IN the genus *Stethorus* are important mite predators in various crops world wide (Kapur 1948, McMurty et al. 1970). Members of this genus are obligate predators of tetranychid mites. Common species in tree fruits include *S. punctillum* Weise, which is widely distributed in the Palearctic Region and more recently established in North America (Putman 1955). *S. punctum picipes* Casey is common in the west (Gordon & Chapin 1983) and in much of the mid-Atlantic region *S. p. punctum* (LeConte) is the major mite predator in tree fruit orchards (Asquith & Hull 1979).

In temperate regions *Stethorus* adults undergo a hibernal diapause. Putman (1955) found that most *S. punctillum* females enter diapause, as determined by ovary retrogression and enlargement of fat bodies, by August and that this species hibernates under leaf litter in woodlands and orchards. He showed that adults survived in sod or on soil under differing amounts of cover, but could not survive above the ground. Adults emerged from artificial overwintering sites over a several-day to several-week period during April through June depending on year. The pattern of emergence was similar between sexes. Adults were first recovered from trees by limb tap sampling within several days to 2 wk after emergence began. Colburn & Asquith (1971) found a similar biology for *S. p. punctum* inhabiting apples in Pennsylvania. They found overwintering adults concentrated in dead leaves surrounding tree trunks and observed them on apple foliage in April. Both studies noted that the adults were fertile upon emergence in the spring.

Those studies, however, did not relate cumulative emergence to degree-day accumulation nor develop a consistent system for monitoring emergence in the spring, both of which would further develop the integrated pest management program in apple production in the mid-Atlantic region. Timing of overwintering emergence is particularly crucial because the key pest, tufted apple bud moth, *Platynota idaeusalis* (Walker), utilizes similar overwintering habitat as *S. p. punctum.* The tufted apple bud moth has developed resistance to some organophosphate insecticides to which *S. p. punctum* had previously developed resistance (Knight & Hull 1992, Biddinger 1993). A switch to carbamate insecticides to control the tufted apple bud moth has resulted in increased mortality of *S. p. punctum* and threatens to disrupt the biocontrol of mites by this important predator (David & Horsburgh 1985, Biddinger 1993). Use of pyrethroid insecticides are also disruptive to *S. p. punctum* unless timed for late in the season (Hull & Knight 1989). Bode (1975) and Knight & Hull (1988) have suggested controlling overwintering tufted apple bud moth larvae in the ground cover. The study reported here was conducted to determine when

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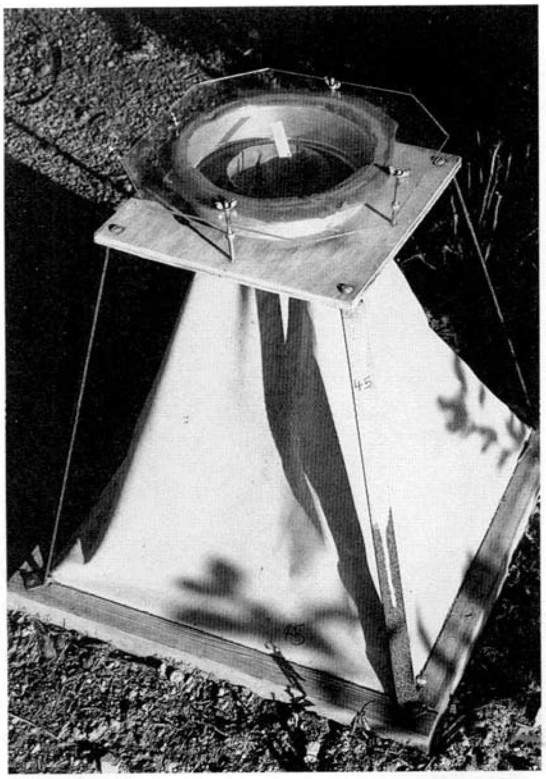

**Fig. 1.** Cage used to determine adult emergence of *S. p. punctum* adults.

an insecticide application could be applied to the ground cover without harming *S. p. punctum* and to examine a sampling procedure for the emerging adults.

## Materials and Methods

**Emergence from Overwintering Sites.** Daily emergence of *S. p. punctum* adults from overwintering sites in the ground cover was measured during 1991–1993 in Biglerville, PA. Adults were trapped using pyramid-shaped cages covering 0.25 $m^2$ of ground area with a reservoir containing ethylene glycol (Fig. 1). The cages consisted of a wooden base, metal supports, a plywood platform (30.5 by 30.5 cm, with a 14-cm diameter opening in the center), and an aluminum collection reservoir (1.1-liter comet ring mold, Mirro, Manitowoc, WI). The aluminum reservoir was modified by cutting off the upper portion of the inner lip. The platform stood 50 cm above the top of the base. A net made of Lumite 25 material (Chicopee, New Brunswick, NJ) sewn into the shape of a pyramid was attached to the inner surface of the base and was folded over the cut-off portion of the reservoir and attached with a rubber band and paper clips. The reservoir was covered with a Plexiglas shield attached to the platform with four bolts and wing nuts. A ring of foam rubber (4 mm thick) glued to the inner surface of the Plexiglas made a seal around the outer lip of the mold. The base was buried 9 cm into the soil.

The cages were placed over sites with a high density of overwintering *S. p. punctum*. These sites were located in February and March using samples of leaf litter from near the trunk of individual trees. Samples of leaf litter from a 0.1-$m^2$ area were held in plastic containers at room temperature for 10 d and adults resting on the lids were counted and removed daily. Emergence cages were placed over leaf litter near the sampling sites from which the most adults were recovered. In 1991 six cages were placed in a single orchard (orchard 1) between 22 February and 9 April at the Pennsylvania State Fruit Research Laboratory, Biglerville, PA. In 1992, orchard 1 was removed so cages were placed in another orchard at the Fruit Research Laboratory (orchard 2) and a commercial orchard (orchard 3) 2 km away. Five and six cages were placed in orchards 2 and 3, respectively, between 4 and 10 April.

In 1993 cages were placed in the same two orchards. In orchard 2, no samples were taken before treatment; cages were placed over sites with high populations in 1992. Snow cover through early April in some areas delayed cage placement. Four and six cages were placed in orchards 2 and 3, respectively, between 31 March and 15 April.

The cages were monitored daily until at least a week after the last adults were collected. Adult *S. p. punctum* were counted and removed from each cage before 1000 hours (EDST) each morning. Adults were trapped when they flew either into the ethylene glycol in the reservoirs or into condensed moisture on the Plexiglas. The number trapped was assigned to the previous day.

Ambient environmental conditions and conditions in the overwintering habitat were monitored during the study. Daily rainfall and maximum, minimum, and average (based on hourly readings) air temperatures were recorded using a Neogen EnviroCaster Research Model Version 0.05 (Neogen, Lansing, MI) in orchard 2 beginning in April each year. Daily temperature of the soil surface under the organic matter was determined using two thermocouple probes, with one located inside and the other outside an emergence cage. Orchard 2 was 0.5 and 2 km from the other orchards in which daily emergence was monitored. Temperature data for March were taken in a site bordering orchard 2 at which daily maximum/minimum temperature and rainfall were recorded. Degree-day (DD) accumulation was determined each year using a base of 5°C, the developmental threshold for the egg through pupal stages of *S. punctillum* calculated from Berker (1958). $DD_{5°C}$ accumulation was begun on 1 March based on average temperatures in the lower Susquehanna Division of Pennsylvania for January, February, and March of −1.6, −0.6, and 4.6°C, respectively (NOAA 1992). Apple phenological development for 'Yorking' was monitored at the Fruit Research Laboratory.

**Emergence Monitoring in Trees.** Overwintered adults were monitored on the apple trees by timed counts and by capture on sticky traps placed in the apple canopy. A 3-min count of adults around the periphery of each of 10 trees was made two times per week from 12 to 20 April 1991 in orchard 1. In 1992 a similar procedure was conducted on 30 April and 7, 11, and 19 May in orchards 2 and 3.

First capture of *S. p. punctum* adults on double-sided yellow sticky traps (22.5 by 14.0 cm, unbaited [Pherocon, Zoecon, Palo Alto, CA]) monitored three times per week was determined in 1992 and 1993. In 1992 monitoring began on 10 and 23 April in orchard 2 and a nearby orchard, respectively. In 1993 monitoring began on 23 April as described below.

**Trapping Study.** A trapping efficiency study was also conducted in 1992 and 1993. Trap color (yellow or white) and presence or absence of a volatile (ammonium carbonate) (two crossed panels each 20.5 by 14.7 cm [Rebell, Swiss Federal Research Station, Wadenswil, Switzerland; supplied by Great Lakes IPM, Vestaburg, MI]) were tested utilizing a factorial combination. In 1992 two traps of each combination were monitored from 8 to 13 July in a site near the former orchard 1. In 1993 a total of 20 traps including six yellow with volatile, six yellow without volatile, four white with volatile and four white without volatile was monitored from 23 April to 21 May in orchard 4 located 5 km from orchard 2. The traps were completely randomized in a 3.2-ha orchard. The traps were placed in a grid (4 by 5) with traps separated by 32 m. *S. p. punctum* adults were removed and traps cleaned three times per week both years. This experiment was analyzed as a completely random design each year with the effects of color and volatile in a factorial arrangement (Abacus Concepts 1989). Based on a significant interaction term, the effect of all treatments was evaluated. Mean separations with log-transformed data were determined using Fisher's protected least significant difference at $P = 0.05$.

## Results

**Emergence from Overwintering Sites.** Most *S. p. punctum* adults were recovered between 100 and 300 $DD_{5°C}$ over the 3 yr of the study (Fig. 2). Emergence was 50% complete at ≈210 $DD_{5°C}$ and paralleled phenological development of apple. Cumulative emergence was 2.3 ± 1.2 (mean ± SEM), 46.7 ± 13.7 and 95.8 ± 1.3 complete by the half inch green, pink, and the petal fall stages of 'Yorking' apple development, respectively, during the 3 yr. Total recovery of *S. p. punctum* adults was 132, 65, and 211 in 1991, 1992, and 1993, respectively. Total capture in orchards 2 and 3 was

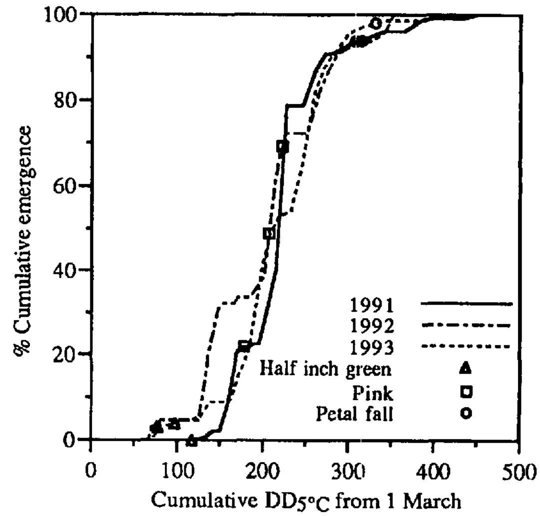


**Fig. 2.** Cumulative emergence of *S. p. punctum* adults from overwintering sites in relation to $DD_{5°C}$ and apple phenological stages, 1991–1993, Adams County, Pennsylvania.

45 and 20, respectively, in 1992, and 6 and 205, respectively, in 1993.

Adults began emerging after the 1st wk in April when the average daily temperatures exceeded 10°C (Fig. 3 A–C). In 1991, early emergence was associated with high temperatures that also accelerated phenological stages. In contrast, delayed adult emergence and tree development were associated with cooler temperatures in 1992. In 1993, most emergence was concentrated during warm periods following cooler periods initially. Over the 3 yr, peak daily emergence occurred between 27 April and 3 May. Emergence did not appear to be related to rainfall events.

Over the 3 yr of the study most adult emergence occurred during days when the temperature averaged 15–20°C (Fig. 4). During the emergence period the daily minimum and maximum temperatures were 5–15°C and 20–30°C, respectively. Few adults emerged on days when the average temperature was <10°C, and emergence was essentially complete by the time average daily temperatures exceeded 25°C.

During the periods of adult emergence from 11 April to 18 May 1992 and from 15 April to 19 May 1993, average daily temperatures under the organic matter of the soil surface were 0.3 ± 0.3°C (mean ± SEM, $n = 2$ yr) warmer outside than inside of the emergence cages. Minimum temperatures were 0.8 ± 0.2°C cooler, and maximum temperatures were 2.5 ± 0.7°C warmer inside the cage. During the 2 yr daily average temperatures outside the cage in the overwintering habitat were 0.7 ± 0.7°C cooler than ambient air temperatures.

**Emergence Monitoring in Trees.** Density of adults in the trees peaked at 75% cumulative emergence in 1991 and then quickly declined (Fig.

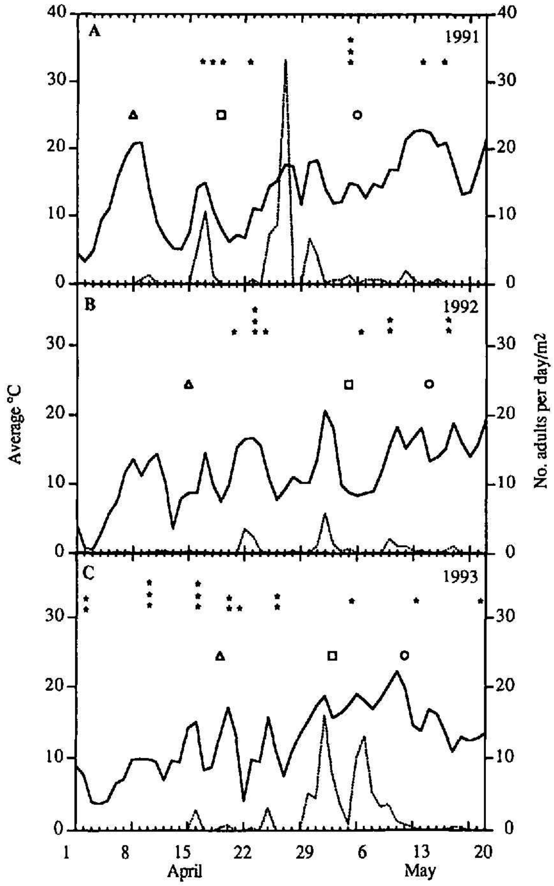


**Fig. 3.** Daily emergence of *S. p. punctum* adults from overwintering sites in relation to average daily temperature, total daily rainfall >0.5 cm (*, **, and *** equal 0.6–1.5, 1.5–2.5, and >2.5 cm, respectively) and phenological stage of apple (Δ, half inch green; □, pink; and O, petal fall), 1991–1993 (A–C), Adams County, Pennsylvania.

5). Observation of adults in the tree canopy paralleled emergence from the overwintering sites. In 1992, few adults were observed on the foliage. Three adults (two on 11 May and one on 19 May) and one adult (19 May) were recorded in orchards 2 and 3, respectively. *S. p. punctum* adults were first captured on yellow boards on 24 April (30% emergence) and on 30 April (20% emergence) in 1992 and 1993, respectively. Yellow boards were not used in 1991.

**Trapping study.** The trap efficiency study resulted in a significant color by volatile interaction in 1992 ($F$ = 15.5; df = 1, 4; $P$ = 0.017) and 1993 ($F$ = 9.258; df = 1, 16; $P$ = 0.008). Therefore, all treatment combinations were analyzed (Table 1). The combined treatment effect was significant in 1992 ($F$ = 15.0; df = 3, 4; $P$ = 0.012) and 1993 ($F$ = 59.3; df = 3, 16; $P$ < 0.0001). The most *S. p. punctum* adults were captured on yellow traps, whether with or without the volatile. Fewest adults

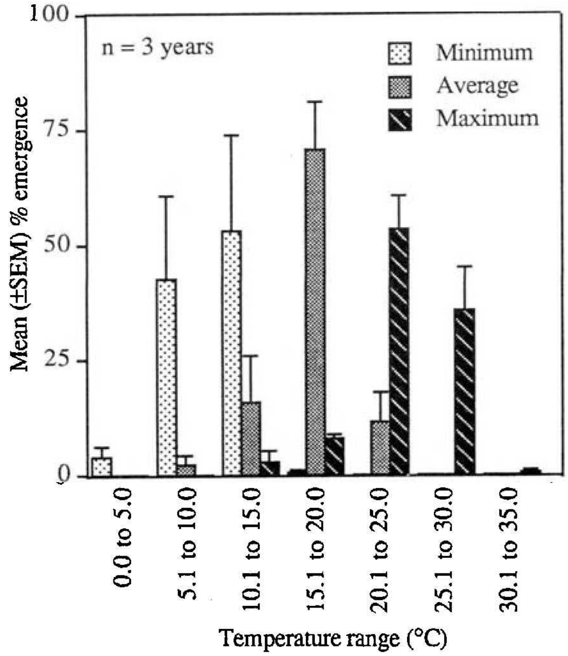


**Fig. 4.** Daily minimum, average, and maximum temperatures during emergence of overwintered *S. p. punctum* adults, 1991–1993, Adams County, Pennsylvania.

were captured on white traps baited with ammonium carbonate.

## Discussion

Hodek (1973) stated that during the closing stages of dormancy coccinellid adults gradually increase their movement based on temperature and

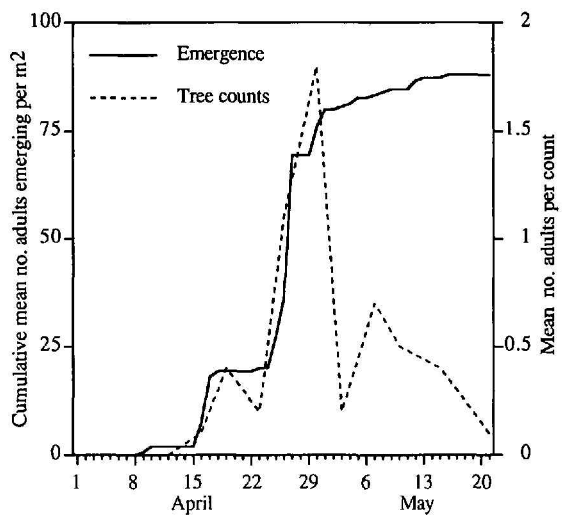


**Fig. 5.** Cumulative emergence of *S. p. punctum* adults and the associated numbers observed in 3-min counts around the tree pheriphery, 1991, Adams County, Pennsylvania.

**Table 1. Capture of *S. p. punctum* adults on two colors of sticky traps with or without the volatile ammonium carbonate in an apple orchard, 1992 and 1993, Adams County, Pennsylvania**

| Treatment | Mean ± SEM no. per trap | |
|---|---|---|
| | 8–13 July 1992 | 26 April–21 May 1993 |
| Yellow sticky trap | 12.5 ± 7.5ab | 38.0 ± 6.5a |
| Yellow sticky trap with volatile | 85.5 ± 24.5a | 65.7 ± 9.1a |
| White sticky trap | 5.5 ± 2.5b | 4.8 ± 1.5b |
| White sticky trap with volatile | 0.5 ± 0.5c | 1.5 ± 0.5c |

Means followed by the same letter are not significantly different ($P > 0.05$, Fisher's protected LSD) based on log-transformed means.

that dispersal occurs over a period of several weeks after a *prolonged period* over 10°C. *S. p. punctum* adults brought inside during February immediately were active at room temperature. Also, adults have occasionally been observed moving on the lower trunks of apple trees during warm periods during the winter (L.A.H., personal observation). Therefore, some movement of adults may have occurred inside the cages before adult flight resulted in capture.

The close association of capture of adults in the emergence cages and observations in trees as observed in this study and by Putman (1955) suggest that these adults move quickly into the apple trees after emergence. Colburn & Asquith (1971) in Pennsylvania and Parrella & Horsburgh (1981) in central Virginia also recorded *S. p. punctum* adults in trees in April. However, cool conditions that prevent flight immediately following an early emergence period may result in a lag time until adults are observed in trees (Putman 1955).

Behaviors after diapause are driven largely by temperature (Tauber & Tauber 1976). Tauber & Tauber (1973) recorded that for the neuropteran *Chrysopa carnea* Stephens diapause ends during the winter, but that diapause characteristics are retained until temperatures exceed 4°C. Reproductive development after diapause in females required ≈100 heat units above 4°C. However, temperatures >8°C were necessary for mating and oviposition. It is not known when development after diapause is completed in *S. p. punctum*. Emergence began at 100 $DD_{5°C}$, but mean cumulative emergence did not occur for an additional 110 $DD_{5°C}$. Further investigations are needed to determine when diapause ends and how development after diapause progresses in this coccinellid.

Yellow traps without volatile appear sufficent to monitor the beginning of emergence after diapause, of overwintered *S. p. punctum*. The traps may provide more accurate observations than foliage counts in some years. Lack of adults in tree counts early in the season in 1992 and 1993 may have been caused by low density, too-long sampling intervals, or cool or windy sampling conditions that may have altered adult behavior (Putman 1955); whereas yellow trap catch numbers represent a cumulative capture over all environmental conditions. Capture of adults in yellow traps as early as 22 April 1993 has also been noted in apple in the Hudson Valley region of New York (R. Straub, personal communication).

Yellow traps are effective for a wide range of other coccinellid species (Maredia et al. 1992a). Yellow color has been shown to be more attractive than white to *Coccinella septempunctata* L. and as attractive as white to *Hippodamia parenthesis* (Say) (Maredia et al. 1992b). White traps were less effective than yellow for *S. p. punctum*, but have been used to document wind-aided flight by *Stethorus* spp. in Australia (Readshaw 1975).

The decline in density in tree counts during May probably resulted from the long-lived adults moving out of the orchard to search for sites with higher densities of the European red mite, *Panonychus ulmi* (Koch) (Hull et al. 1977). However, Hull et al. (1976) found no significant correlations between *S. p. punctum* and mite populations early in the season. They noted that during that period leaf expansion results in decreasing mite density. Generally, *S. p. punctum* densities do not build up in treated orchards until June or July when mite populations typically increase to damaging levels. Although *S. p. punctum* may feed on twospotted spider mites, *Tetranychus urticae* (Koch) in ground cover vegetation, this behavior has not been commonly observed in apple orchards in Adams County (L.A.H, personal observation). The role of rare mite patches on apple and on alternate plant hosts regarding *S. p. punctum* early-season ecology has not been thoroughly investigated.

Long-range host-finding studies concerning *Stethorus* have been few, although response of *S. p. punctum* to mite-infested branches led Hull et al. (1977) to speculate that search is nonrandom. Congdon et al. (1993) also found *S. p. picipes* on rare host patches and suggested that mechanisms of area-restricted search or chemotaxis or both lead to aggregation. Downwind dispersal of *Stethorus* spp. to trees of high mite density (Readshaw 1975) suggest a possible visual response. The high attractancy to yellow observed may result from a visual stimulus to leaves damaged (*bronzed*) as a result of high mite density. The volatile also may provide a cue similar to that from damaged leaves and cause a combined effect with the favorable visual cue as occurs with many herbivorous insects (Prokopy & Owens 1983). The reason for the inhibitory effect of the white plus the volatile is unclear.

Overwintering larvae of tufted apple bud moth feed on apple root suckers and broad-leaved weeds in the ground cover (Knight & Hull 1988), with adult emergence beginning in late petal fall and continuing for at least six more weeks. Because emergence of *S. p. punctum* is virtually complete by petal fall, there appears to be a *window of opportunity* where applications of pyrethroids or any insecticides toxic to tufted apple bud moth may be made at petal fall or later without causing mortality of the coccinellid predator and risking mite flare-ups (Felland & Hull 1992). Applications of insecticides to the ground cover after *S. p. punctum* emergence may play an important role in reducing overwintering tufted apple bud moth populations and the subsequent need to apply repeated insecticide applications to the tree later in the growing season. This tactic would also enable growers to attempt to manage organophosphate resistance in tufted apple bud moth by switching to other classes of insecticides (i.e., pyrethroids) while not disrupting the interaction between mites and *S. p. punctum*.

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