Impact of Insecticide Application and Mass Trapping on Infestation by Strawberry Sap Beetles (Coleoptera: Nitidulidae)[1]

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J. Entomol. Sci. 37(4): 300-307 (October 2002)

Abstract The impact of insecticide application and mass trapping on the level of infestation by the strawberry sap beetle, *Stelidota geminata* Say (Coleoptera: Nitidulidae), was assessed in cultivated strawberry. In total, more than 17,000 adults were captured in traps baited with whole wheat bread dough. Early in the season, captures were similar for traps at the periphery of and within the strawberry field, whereas captures were lowest within the field after fruits had begun to ripen. The presence of peripheral traps slightly increased captures of adults within the strawberry planting, suggesting that mass trapping of adults with food-baited traps may not be a viable management strategy. Applications of fenpropathrin at dusk or mid-day, between the appearance of ripe fruits and the first harvest, reduced infestation of fruits by sap beetle larvae. Fruits located on the ground were more heavily infested by sap beetles than fruits in the plant canopy, which either is due to foraging movements of adults on the ground or reflects differential suitability of strawberry fruits as a food resource for sap beetles. A positive relationship between captures of adults in traps and the abundance of ripe fruits suggests that the spatial distribution of foraging adults is influenced by the availability of food resources.

Key Words *Steldota geminata, Fragaria x ananassa,* mass trapping, dispersal fenpropathrin

The strawberry sap beetle, *Stelidota geminata* Say (Coleoptera: Nitidulidae), is a major pest of cultivated strawberry, *Fragaria x ananassa* Duchesne, throughout North America (Connell 1980). Damage is inflicted by adults or larvae feeding on ripe fruits. Contamination of fruits by larvae is of particular concern to consumers and may result in total crop loss (Weber and Connell 1975, Sorensen 1996). In cage experiments, adult sap beetles confined with insecticide-treated strawberry plants suffer high levels of mortality (Williams and Fickle 1998, Williams et al. 1999). In the field, however, control of sap beetles with insecticides may be difficult, because cryptic adults and larvae infest ripe fruits shortly before harvest (Weiss and Williams 1980, Williams et al. 1992, 1996).

Because sap beetles are believed to overwinter in woodlots and progressively migrate into strawberry fields as fruits begin to ripen, it has been hypothesized that populations could be managed by disrupting the migration of adults from woodlots into strawberry fields (Miller and Williams 1982, Blackmer and Phelan 1995, Williams et al. 1996). Traps baited with whole wheat bread dough are highly attractive to adult

[1]Received 05 December 2001; accepted for publication 31 March 2002.

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sap beetles (Miller and Williams 1982, Williams et al. 1993, 1994, 1996), and placement of traps along the periphery of strawberry fields has been proposed as a management strategy (Weiss and Williams 1979). To date, however, no studies have quantified the impact of mass trapping of adults on subsequent infestation by sap beetles. Therefore, the objective of this study was to assess the impact of insecticide application and mass trapping on the level of infestation by sap beetles in cultivated strawberry.

Materials and Methods

The study was conducted in 2001 near Lockport, NY, in a 1.50-ha, 3-yr-old planting of strawberry (cv 'Jewel') chronically infested by sap beetles. The experimental site consisted of three 136-m long rows of strawberry plants located at the edge of the field, about 8-m east from a woodlot. The site was divided in three 40-m long plots, with each plot subdivided into two 16-m long plots. A distance of 8 m separated plots and subplots. For each plot, a grid of traps was placed between the woodlot and strawberry field in one randomly selected subplot. For each plot and subplot, rows of strawberry plants were divided into five 4-m long sections randomly assigned to one of five insecticide treatments.

The density of sap beetles in the experimental site was estimated using traps baited with 40 g of whole wheat bread dough (Williams et al. 1994). The bread dough was enclosed in a small cheesecloth bag to prevent beetles from becoming imbedded in the dough. Each trap consisted of a 1-L plastic container covered with a 16-mesh wire screen. The screen allowed sap beetles to enter the traps but excluded larger insects. Traps were placed inside 10-cm diam holes into the ground, with the top of traps even with the soil surface. Each trap was covered with a 15 × 15 cm plywood rainshield mounted on 4-cm legs. For each plot and subplot, one trap was placed in the center of 4-m long row sections with strawberry plants, corresponding to a total of 30 traps within the field. In one half the subplots, 20 traps equidistantly spaced were placed between the woodlot and the strawberry planting, for a total of 60 traps along the field border. Traps were replaced every 5 to 7 d, and returned to the laboratory to count beetles captured. The relationship between the location of fruit and the presence of adult beetles was assessed on 18 June by harvesting ripe fruits in 5 randomly selected locations outside of the experimental plot. Fruits were assigned to one of four categories: (1) touching the ground or straw, adults present; (2) touching the ground or straw, adults absent; (3) not touching the ground or straw, adults present; and (4) not touching the ground or straw, adults absent. In total, 583 fruits were censused (84 to 142 fruits per location).

For each plot and subplot, the efficacy of insecticide was evaluated by assigning 4-m long rows of strawberry plants to one of five insecticide treatments: (1) no insecticide; (2) one application of fenpropathrin (Danitol 2.4 EC; Valent Corp., Walnut Creek, CA 94596-8025) at first ripe fruits (14 June) at dusk; (3) one application of fenpropathrin at first harvest (approximately 20% of king berries and second berries ripe; 18 June) at mid-day; (4) one application of fenpropathrin at first harvest at dusk, and (5) two applications of fenpropathrin, one at first ripe fruits and the second at first harvest, at dusk. For all applications, fenpropathrin was sprayed at a rate of 0.8 L/ha (374 L/ha of water) using a CO_2 pressurized backpack sprayer operated at 2.8 kg/ cm^2. Each insecticide treatment was replicated 6 times.

The level of infestation by larvae was quantified by harvesting all ripe fruits from two 0.5-m long subsamples in the center row of 4-m long sections with strawberry plants on 1 July. Fruits were divided in two categories, according to whether they touched the ground or not. The incidence of infestation was assessed by crushing fruits and soaking them in water to extract larvae.

Statistical analyses were conducted with SAS statistical package (SAS Institute 1988). Generalized linear modelling was used to assess the relative abundance of sap beetles in food-baited traps (y) as a function of time (x_1), location of traps (x_2: periphery of or within the strawberry field) and replicate (x_3), with x_1 and x_2 treated as fixed factors, and x_3 as a blocking factor [proc glm; class x_1 x_2 x_3; model $y = x_1|x_2\ x_3$]. Captures of sap beetles within the strawberry field (y) were compared for different time periods (x_1), insecticide treatments (x_2), mass trapping treatments (x_3; plots with or without peripheral traps), and replicates (x_4) using generalized linear modelling, with x_1, x_2, and x_3 treated as fixed factors, and x_4 as a blocking factor [proc glm; class x_1 x_2 x_3 x_4; model $y = x_1|x_2|x_3\ x_4$]. The incidence of sap beetle larvae per strawberry fruit (y) was evaluated in relationship with insecticide treatment (x_1), mass trapping treatment (x_2), location of fruit (x_3; strawberries on the ground or in the plant canopy) and replicate (x_4) using generalized linear modelling, with x_1, x_2, and x_3 treated as fixed factors, and x_4 as a blocking factor [proc glm; class x_1 x_2 x_3 x_4; model $y = x_1|x_2|x_3\ x_4$]. Correlations were used to compare the relationship between number of sap beetles captured within the strawberry field after the appearance of ripe fruits and either the number of fruits harvested per plot, the number of larvae per plot, or the number of larvae per fruit per plot.

Results and Discussion

Captures of adult sap beetles in the periphery of and within the strawberry field. In total, more than 17,000 adult beetles were captured in traps baited with bread dough throughout the season. Adult sap beetles were not sexed, and it remains unknown whether the sex-ratio varied as a function of time or location of traps. The relative abundance of sap beetles varied with time, with a low incidence early in the season (17 May-7 June), a peak of about 100 adults per trap between 7-14 June, and then a steady decline thereafter (Fig. 1). Comparing the relative abundance of sap beetles in the periphery of and within the strawberry field revealed a significant interaction between time and location of traps ($F = 10.33$; df = 6, 611; $P < 0.0001$). Early in the season, captures of beetles were similar for traps located at the periphery of and within the strawberry field; however, captures of sap beetles were highest in peripheral traps after strawberry fruits had begun to ripen in late spring (Fig. 1).

Large number of sap beetles captured along the field border (Fig. 1) partially supports the hypothesis that adults overwinter in woodlots and progressively invade agricultural fields later in the season (Miller and Williams 1982, Blackmer and Phelan 1995, Williams et al. 1996).

However, captures of sap beetles at the periphery of and within the field exhibited a similar trend early in the season (Fig. 1), suggesting that adults may either overwinter within strawberry fields, or colonize strawberry plantings in early spring. Extremely low captures of sap beetles early in the trapping season (<0.1 adult per trap; Fig. 1), however, strongly suggest that adults did not colonize the strawberry field in early spring. Fungi and decaying organic matter in the litter of strawberry fields may provide an alternate food source that support significant populations of sap beetles throughout the growing season, and the presence of straw mulch may facilitate over-

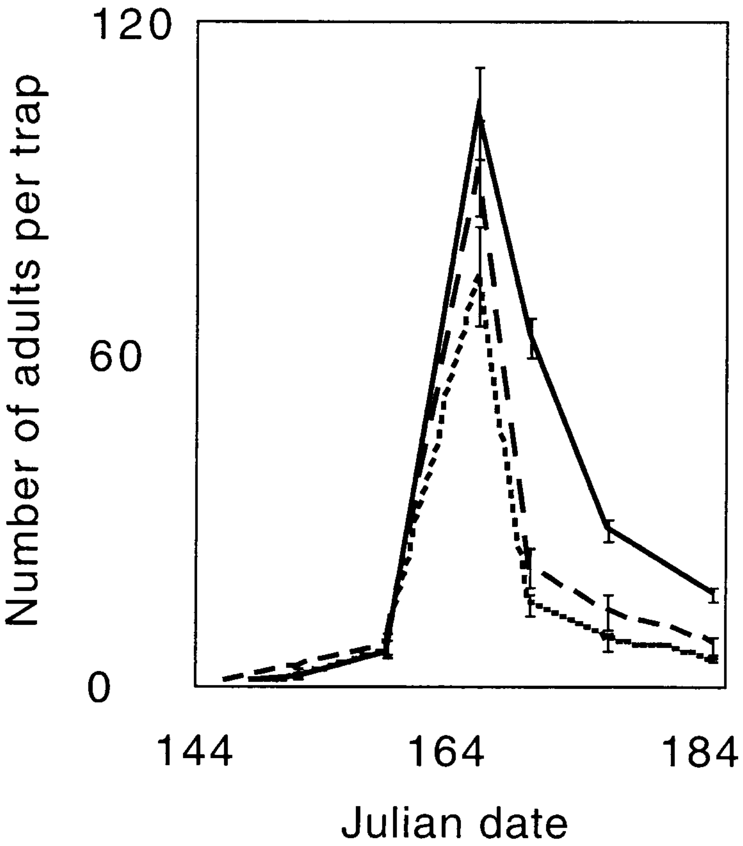

Fig. 1. Mean number (±SE) of adult sap beetles captured in traps baited with whole wheat bread dough in spring-early summer 2001 in a strawberry farm located near Lockport, NY. Traps were either placed along the border of the strawberry planting (________) or within the strawberry planting in sections bordered (— — —) or not bordered (--------) with periphery traps.

wintering survival of adults. Relatively low captures of adults within the strawberry field in late spring (Fig. 1) may be attributed to the presence of numerous fruits reducing the attractiveness of bread dough as a food bait (Miller and Williams 1982).

Within-plant location of sap beetles. In the census conducted at 5 locations, 28 of 583 fruits (4.8%) were infested with adult beetles. The mean percentage (±SE) of fruits infested with adults was much higher for fruits in contact with the ground (7.92 ± 2.66) than for fruits in the plant canopy (0.41 ± 0.41). In total, 734 sap beetle larvae were recovered from 1633 fruits, for an average of 0.45 larva per fruit. The level of larval infestation was greater for fruits harvested on the ground rather than in the plant canopy (F = 9.31; df = 1, 38; P = 0.004) (Fig. 2).

Many sap beetle species are generalist feeders that exploit a wide range of hosts, including ripe fruits of numerous plant species, sap from fresh tree wounds, pig

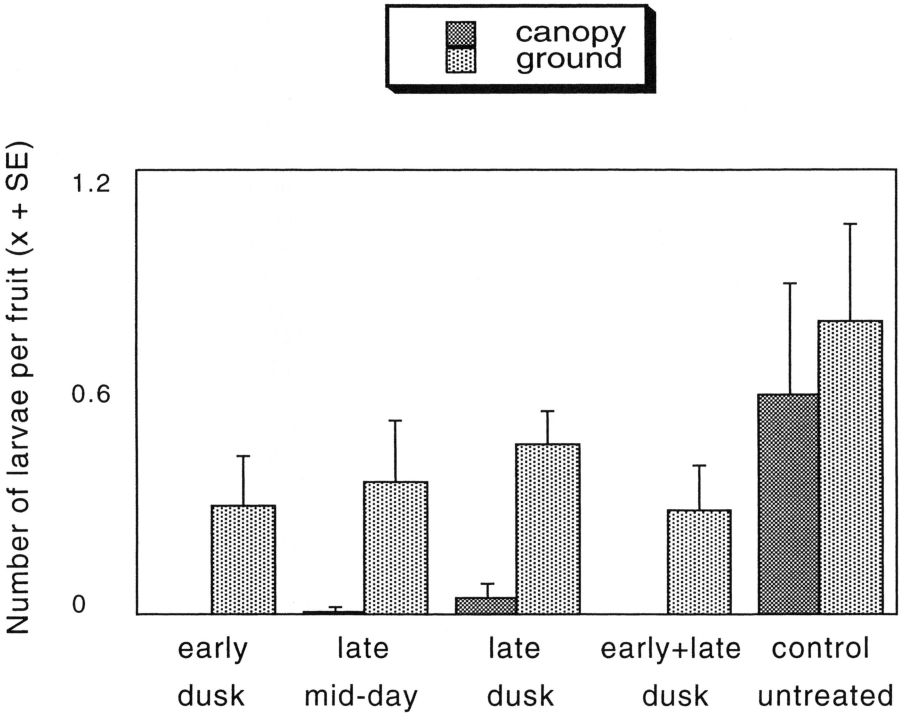

Fig. 2. Mean number (±SE) of sap beetle larvae on strawberry fruits harvested on the ground or in the plant canopy in plots treated with fenpropathrin (0.8 L/ha) or untreated. Fenpropathrin was applied once or twice, either early (first ripe fruits; 14 June 2001) or late (first harvest on 18 June 2001; approximately 20% of king berries and second berries ripe) in the season at mid-day or dusk.

carrion, and fungi (Blackmer and Phelan 1992). Because hosts of sap beetles are usually available for a short period and occur in discrete patches, resource location by adults most likely involves long-range flight dispersal between patches (Blackmer and Phelan 1992, Williams et al. 1993). Higher captures of strawberry sap beetle adults in traps at ground level rather than 1.5 m above ground (Williams et al. 1993), however, suggests that adults forage on the ground to locate hosts. The higher incidence of adults and larvae in strawberry fruits located on the ground rather than in the plant canopy (Fig. 2; Weiss and Williams 1979, Connell 1980) indirectly supports the hypothesis that adults forage on the ground. Alternatively, it may also reflect differential suitability of strawberry fruits as food resource for sap beetles, with variations in shading, moisture and/or ripeness possibly affecting the development of larvae.

Impact of insecticide application on sap beetle populations. In cage experiments, several insecticides are lethal to adult sap beetles (Williams and Fickle 1998, Williams et al. 1999), but no field studies had yet evaluated the impact of insecticide application on the level of infestation of strawberry fruits. Although insecticide treatment did not reduce captures of adults in food-baited traps ($F = 0.60$; df = 4, 138; P

= 0.663), incidence of larvae per fruit was lower in raw sections treated with fenpropathrin than in control row sections (F = 0.31; df = 1.38; P = 0.0004) (Fig. 2). Timing of insecticide application did not affect the level of control, as indicated by similar incidence of larvae on strawberry plants treated once or twice at mid-day or dusk (generalized linear modelling excluding control plots: F = 0.65; df = 3, 30; P = 0.590) (Fig. 2). Insecticide treatment reduced larval infestation to a lower extent for fruits on the ground when compared to infestation in the plant canopy (Fig. 2), suggesting that the dense leaf cover of strawberry plants may prevent insecticide from reaching the ground (Williams et al. 1996). Alternatively, the relatively high incidence of larval infestation in insecticide-treated row sections may be attributed to migration of adult sap beetles from surrounding untreated field section into the experimental plot. Because consumers have a zero tolerance threshold for sap beetle larvae, large-scale trials are needed to determine whether an application of fenpropathrin over entire strawberry fields would effectively suppress larval infestations.

Potential use of food-baited traps as a management strategy. The presence of peripheral traps slightly increased captures within the strawberry field (F = 6.11; df = 1, 138; P = 0.015) (Fig. 1), but had no impact of the incidence of larvae per fruit (F = 0.92; df = 1, 38; P = 0.344). Captures of adults in the strawberry field after the appearance of ripe fruits (11 June to 1 July) were positively correlated with the abundance of fruits per 1-m long harvested section (Fig. 3). There was no significant relationship between captures of adults and density of larvae per plot (r = 0.254; P = 0.175) or per fruit per plot (r = 0.122; P = 0.521).

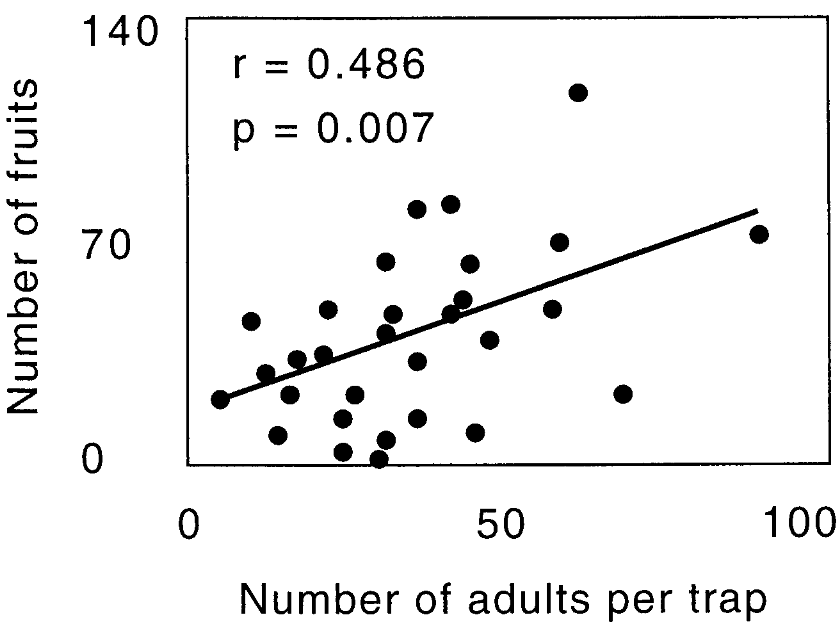

Fig. 3. Relationship between the number of adult sap beetles captured in traps baited with whole wheat bread dough after the appearance of ripe strawberry fruits (11 June to 1 July) and density of fruits per plot.

Traps placed at the periphery of the strawberry planting captured numerous adult sap beetles but did not reduce infestation of fruits by larvae, indicating that mass trapping of adults with food baited traps is not a viable management strategy. On the contrary, the presence of traps at the field border unexpectedly increased captures of adults within the strawberry planting, although the impact was relatively small (Fig. 1). This result suggests that 'mass trapping' may have an adverse effect by increasing local populations of adults that colonize strawberry fields. The positive relationship between captures of sap beetles and abundance of fruits (Fig. 3) also suggests that the spatial distribution of foraging adults is influenced by the availability of food resources. On the other hand, the absence of a significant relationship between captures of adults and incidence of larvae indicates limited potential use of bread dough-baited traps to predict larval infestation on a small spatial scale. On a large scale, however, trap catches may be used as a monitoring tool to assess year-to-year variations of sap beetle populations, and possibly to determine when control measures are justified.

Acknowledgments

We are grateful to J. Eugene, S. Hessler, S. Fishel, A. Gillespie, C. Loomis, L. Minns, J. Nyrop, J. Ogrodnick, and S. Villani for field assistance, R. Rieckenberg for assistance with the experimental design, and J. Coulter for allowing us to conduct research at his farm. We also thank R. N. Williams and two anonymous reviewers for comments on early versions of the manuscript. Funding was provided by the New York Berry Growers Association, and insecticide was donated by Valent Corp, Walnut Creek, CA 94596-8025.

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