Effects of Spined Soldier Bug (Hemiptera Pentatomidae) Augmentation and Sticky Barrier Bands on Gypsy Moth (Lepidoptera: Lymantriidae) Density in Oak Canopies[1, 2]

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J. Entomol. Sci. 29(3): 339-346 (July 1994)

ABSTRACT The effects of sticky barrier bands, augmentative releases of the spined soldier bug, *Podisus maculiventris* (Say), and the deployment of *P. maculiventris* pheromone on gypsy moth, *Lymantria dispar* (L.), larval density in the canopy of oak trees were tested. Sticky barrier bands used alone reduced larval gypsy moth density by ≈35%. The release of 5,810 *P. maculiventris* nymphs per tree or the deployment of *P. maculiventris* pheromone to trees on which sticky barrier bands had been applied had no additional effect on gypsy moth larval density. None of the treatments affected the number of gypsy moth egg masses produced. Significantly more *P. maculiventris* adults were observed on trees with the pheromone, but higher numbers of nymphs were not subsequently observed on these trees. Counts of gypsy moths beneath burlap bands prior to gypsy moth pupation were about four times higher on unbanded than on banded trees, but counts of pupae beneath burlap bands did not differ between treatments.

KEY WORDS Biological control, augmentation, mechanical control, barrier bands, *Lymantria dispar, Podisus maculiventris.*

Sticky barrier band have been found to reduce the number of gypsy moth, *Lymantria dispar* (L), larvae in oak canopies by preventing them from ascending trees (Webb and Boyd 1983, Blumenthal and Hoover 1986, Thorpe et al. 1993). However, because gypsy moth larvae that remain in the canopy are unaffected by the bands, further reduction in larval density in the canopy can occur from factors that (a) increase rates of mortality of gypsy moth larvae in the canopy, and/or (b) increase rates of movement of larvae from the canopy to the ground.

[1] Accepted for publication 29 April 1994.

[2] The use of proprietary names in this article is necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

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Adults and nymphs of the spined soldier bug, *Podisus maculiventris* (Say), are known to feed on a variety of insects. McPherson (1982) lists a host range, based on laboratory and field observations, encompassing eight orders of insects, and *P. maculiventris* is a known predator of gypsy moth larvae (Smith and Lautenschlager 1981). Both nymphs and adults are voracious predators, and nymphs have been observed attacking prey much larger than themselves (Warrin and Wallis 1971). Populations of Colorado potato beetle, *Leptinotarsa decemlineata* (Say), on potato have been successfully reduced by augmentative releases of *P. maculiventris* in field cages (5-10 nymphs per plant) (Biever and Chauvin 1992) and in experimental plots in the Soviet Union (100,000 nymphs per ha) (Boiteau 1988).

Secretions from large dorsal abdominal glands in the males attract adults of both sexes (Aldrich et al. 1984). An attractant for *P. maculiventris* (Soldier Bug Attractor™) is commercially available (Anonymous 1992) that may be useful for attracting overwintered adults to individual trees in large numbers. Attraction of *P. maculiventris* to individual trees in numbers sufficient to establish populations might decrease gypsy moth larval density in trees with barrier bands by killing the caterpillars, or by causing the caterpillars to drop from the trees, with the barrier bands preventing their reascent. The objective of this study was to determine the effects of barrier bands on gypsy moth numbers in oak trees when used separately or in conjunction with *P. maculiventris* pheromone or mass releases of *P. maculiventris* nymphs.

Materials and Methods

The study was conducted in a 17-ha predominantly oak woodlot in Baltimore Co., MD, in 1989. The egg mass density in the study area was estimated to be 1,046 (± 113, SE) per ha, based on 40 0.01-ha fixed-radius surveys (Kolodny-Hirsch 1986). Ten groups of four oak trees of similar size, separated from each other by a minimum of 50 m, were selected within the woodlot to serve as replicates. The four trees within each group were within 20 m of each other. The canopies of all trees in the experiment were touching those of adjacent trees. Five of the groups were composed of red oaks, *Quercus rubra* L., and five groups were composed of white oaks, *Q. alba* L. Each of the four trees within a group received a different treatment. The four treatments were (1) sticky barrier band + pheromone, (2) sticky barrier band + augmentative releases of nymphs, (3) sticky barrier band alone, and (4) untreated control. REPEL 'M II™ (REPEL 'M Distributers, Inc., Westport CT) sticky barrier bands were applied to the trees at a height of ≈ 1.5 m. These bands, which are a thin foil strip with a sticky coating, are highly effective at preventing gypsy moth larvae from crossing (Webb and Boyd 1983). *P. maculiventris* pheromone lures (≈ 20% active ingredient in 250 mg polyvinyl chloride matrix as described in Aldrich et al. [1984]) were attached with nails to the tree boles at a height of ≈ 2 m. Lures were replaced every 3-4 d beginning April 4. A total of 5,810 newly-emerged *P. maculiventris* nymphs per tree were released over five dates from April 28 to May 24. Releases were made on five separate dates by attaching small open containers with nymphs to the boles of the trees above the barrier bands. Nymphs were obtained from eggs laid by females attracted to traps at the Beltsville Agricultural Research Center, Beltsville, MD with *P. maculiventris* pheromone (J. R. Aldrich, unpublished data). Gypsy moth larvae were instars 1-4 during the time that the predators were released. For at least 2 d after nymphs were released, a visual examination of the entire tree bole (up to the canopy) was made, and all *P. maculiventris* adults and nymphs were counted.

Burlap bands were placed around each of the trees within each group. The burlap was positioned 5-10 cm above the sticky bands, or at a height of ≈ 1.5 m on trees without sticky bands. At 4-9 d intervals, starting on June 2, when gypsy moth larvae were predominantly fourth instars, counts were made of all gypsy moth larvae and pupae found beneath each burlap band.

Late-instar gypsy moth population density prior to the onset of pupation was estimated in each plot using the frass drop/frass yield method (Liebhold and Elkinton 1988a,b). The number of frass pellets falling per m^2 of ground surface beneath the canopy of each tree was estimated by placing four cardboard panels (66 × 51 cm) coated with Tanglefoot™ (The Tanglefoot Co., Grand Rapids, MI) at random locations beneath the canopy. The number of frass pellets falling on each panel during a single 12 to 16 hour period from afternoon until morning was used to derive an estimate of the amount of frass falling per m^2 of ground surface beneath the canopy. Frass yield (the amount of frass produced per larva during the sampling period) was determined by collecting 100 larvae from the plot at the same time that the panels were deployed and placing them individually in 177-ml plastic cups with cardboard lids. The cups were each provisioned with one or two oak leaves and were then distributed throughout the plots. These larvae were removed from the cups at the same time the frass samples were collected from the plots, so that the sampling duration and temperature conditions experienced by larvae in the cups and in the canopy were similar. The mean density of larvae per plot was estimated using the equation (Liebhold and Elkinton 1988b):

$$\text{Density} = C \bullet (x_d/x_y)$$

where C = 1/(area sampled by each frass sampling device); x_d = mean drop (frass/trap); x_y = mean yield (frass/larva). The number of larvae per tree was estimated by measuring the perimeter of the dripline of each tree, calculating the area contained within the dripline, and multiplying this area by the estimated larval density per unit of area.

We used binoculars to count the number of new egg masses on each tree in the study, both before egg hatch in the spring and after oviposition in the fall.

Frass drop, egg mass, and insect count data were analyzed by analysis of variance using the General Linear Models procedure of the SAS statistics package (SAS Institute 1985). The data were analyzed as a randomized block design, with groups of four trees as the blocking factor, with each of the four trees assigned a different treatment, and using the block x treatment interaction effect as the error term to test the significance of the treatment effect. When the treatment effect was significant, means were separated at a comparison-wise error rate of 0.05 using the least significant differences (LSD) procedure.

Variance homogeneity for each dependent variable was tested by determining the Spearman correlation between the predicted values and the absolute values of the residuals (actual minus predicted response). A significant correlation coefficient indicated that a transformation was needed to stabilize variance. This was accomplished using either a square root transformation or a logarithmic transformation of the form $Y_{transformed} = \ln(Y + \text{constant})$ (Berry 1987). For each analysis, a constant resulting in the most homogeneous variance was used for the transformation (Carrol and Ruppert 1988).

Results

Numbers of larvae per m^2 of canopy ranged from 9.5 to 17.8 in the different treatments (Table 1). These values corresponded to estimates of 911.7 to 1705.1 larvae per tree. This density was low enough that no noticeable defoliation occurred. The number of larvae per m^2 was significantly higher in unbanded than in banded trees ($F = 5.2$; df = 3, 27; $P = 0.006$), but there were no significant differences attributable to the deployment of *P. maculiventris* nymphs or pheromone. No significant differences in the number of egg masses produced per tree occurred among the treatments ($F = 0.3$; df = 3, 27; $P = 0.8$) (Table 1). Many more *P. maculiventris* adults were observed on the trees with pheromone lures, mostly in the vicinity of the lures ($F = 37.8$; df = 3, 27; $P < 0.0001$). However, there is no evidence from these observations that the attracted adults oviposited on the trees, as very few nymphs were subsequently observed. Cumulative numbers of *P. maculiventris* nymphs observed were highest on the trees on which they were released ($F = 18.3$; df = 3, 27; $P < 0.0001$) (Table 1).

The number of live gypsy moth larvae and pupae beneath burlap bands from June 2 to July 25 is shown in Fig. 1. Prior to the onset of pupation, the number of larvae under burlap was from 5 to 7 times higher in trees without sticky barrier bands. Differences in the number of gypsy moths under burlap between unbanded trees and banded trees were significant until July 7, at which time population had reached 86%. After this date there was no difference among the treatments in pupal numbers.

Discussion

Under the low gypsy moth population density conditions that occurred during this study, the sticky barrier bands significantly reduced the number of larvae in the canopy. The degree of reduction (about 35%) is consistent with the results of similar studies conducted under higher density conditions (Thorpe et al. 1993). There was no evidence that the efforts to augment *P. maculiventris* populations affected gypsy moth density in the tree canopies. The focus of this study was to assess the effects of the treatments on gypsy moth density, and no attempt was made to quantify *P. maculiventris* numbers in the canopy. Therefore, it is not possible to determine if the lack of treatment effects resulted from a failure of treatments to increase the numbers of *P. maculiventris* in the canopy, or from a failure of increased numbers of *P. maculiventris* to reduce larval populations. Observations of *P. maculiventris* adults and nymphs on the boles of trees (Table 1) suggested that the pheromone succeeded in attracting *P. maculiventris* adults, but that high populations of nymphs did not subsequently develop on these trees. Future studies should include methods for estimating *P. maculiventris* density in tree canopies.

Table 1. Estimated number of gypsy moth larvae and egg masses and cumulative number of *Podisus maculiventris* adults and nymphs observed on trees treated with various combinations of sticky barrier bands, augmentative releases of *P. maculiventris* nymphs, and *P. maculiventris* pheromone, Baltimore Co., MD, 1989 (n = 10)*.

Treatment	No. larvae/m^2 (SE = 1.5)	No. larvae/tree (SE = 204.3)	Pre-season egg masses /tree** (SE = 0.05)	Post-season egg masses /tree† (SE = 0.2)	No. of *P. maculiventris* observed on tree: Adults (SE = 0.6)	No. of *P. maculiventris* observed on tree: Nymphs** (SE = 0.2)
Barrier band	11.6 a	1154.8	3.0 a (11.1)	1.6 a (2.7)	0.3 a	0.1 a (0.2)
Band + nymphs	12.9 a	1239.9	2.9 a (9.0)	1.6 a (2.7)	0.3 a	1.4 b (3.2)
Band + pheromone	9.5 a	911.7	3.0 a (11.0)	1.8 a (3.3)	8.1 b	0.1 a (0.2)
Control	17.8 b	1705.1	3.1 a (12.3)	1.5 a (2.3)	0 a	0.1 a (0.1)

* Means within a column followed by the same letter are not significantly different at the 0.05 comparison-wise error rate. SE, standard error of mean.
** Data were transformed to logarithms prior to analysis. Back-transformed means are given in parentheses.
† Data were transformed to square roots prior to analysis. Back-transformed means are given in parentheses.

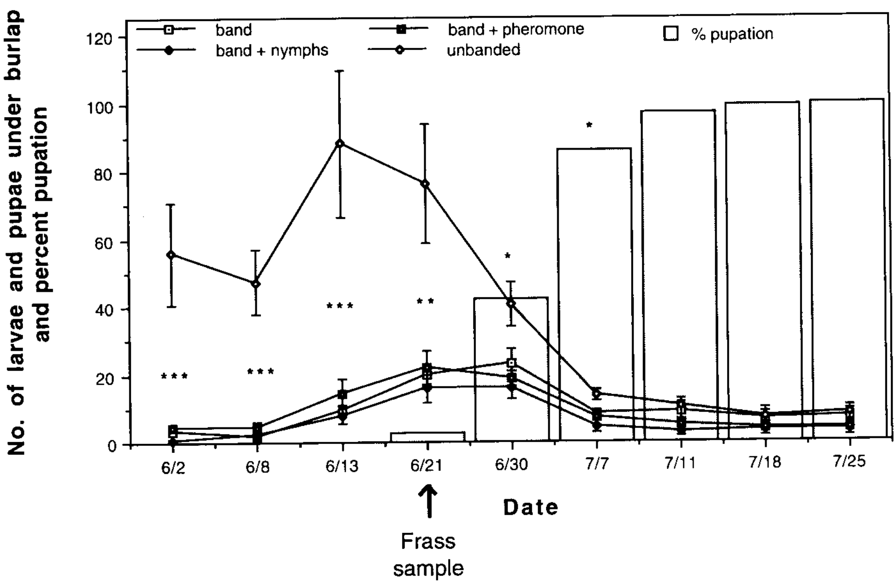

Fig. 1. Number of live gypsy moth larvae and pupae under burlap bands on trees treated with various combinations of sticky barrier bands, *Podisus maculiventris* nymphs, and *P. maculiventris* pheromone, and percent pupation on the indicated dates, Baltimore County, MD, 1989. Asterisks indicate significant differences among the treatments with the following probabilities: *, $0.05 > P > 0.001$; **, $0.001 > P > 0.0001$; ***, $P. < 0.0001$.

In a somewhat related effort to augment populations of a gypsy moth predator, Weseloh (1993) used barrier bands and poison baits to reduce the numbers of forest ants in some experimental plots and sugar sprays to attract ants to other plots. The treatments succeeded in altering ant numbers, and fewer young gypsy moth larvae were present in the plots with reduced ant numbers. However, impacts of the predator on gypsy moth populations in the canopy were not assessed.

The final number of pupae under burlap did not differ among treatments, and therefore did not agree with the numbers of gypsy moth larvae based on the frass samples. This is not surprising, because counts of larvae and pupae under burlap bands may not be representative of local gypsy moth population density (Liebhold et al. 1986). Evidence of this was that, on June 21, the difference found between banded and unbanded trees was much larger using the burlap method than the frass drop method. The larger difference found in the burlap sample probably occurred because some of the larvae found under the burlap bands on trees without sticky barrier bands arrived there by climbing up the bole of the tree from the surrounding area, rather than by descending from the canopy (the burlap bands were positioned above the sticky barrier bands). This further indicates that care should be taken when using counts of larvae and pupae under burlap bands as estimates of gypsy moth population density in the canopy.

Over 58,000 *P. maculiventris* nymphs were produced for the test from adults caught in pheromone-baited traps during the first two weeks of April (J. R. Aldrich, unpublished data). Although the augmentation experiments against gypsy moth caterpillars were inconclusive, we have demonstrated that large numbers of immature *P. maculiventris* can be produced using the synthetic pheromone to harvest wild *P. maculiventris* adults. Hardware and protocols which will enable individual gardeners and growers to mass produce *P. maculiventris* are currently being developed (J. R. Aldrich, unpublished).

Acknowledgments

We thank R. Marocco for allowing us to conduct this study on his property, and C. Curro, F. Daniels, S. Harrison, R. Johnson, L. Krichten, R. Langford, D. Meade, P. Secoura, R. Tatman, L. Venables, and K. Wick, Maryland Department of Agriculture, for assistance in applying the barrier bands and collecting data.

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