EFFECTS OF GROUND-BASED APPLICATIONS OF SOAP, *BACILLUS THURINGIENSIS*, CYFLUTHRIN, AND TRUNK BARRIERS ON GYPSY MOTH DENSITY AND DEFOLIATION

by Kevin W. Thorpe

Abstract. The combined effect of insecticide applications using hydraulic equipment and sticky trunk barriers was tested on individual white oak *(Quercus alba)* trees under heavy gypsy moth *(Lymantria dispar)* pressure. The insecticides tested were insecticidal soap, *Bacillus thuringiensis* (B.t.), and cyfluthrin. One week after treatment, the B.t. and cyfluthrin treatments reduced larval density from 500 larvae per m^2 of ground surface beneath the canopy on unsprayed, unbanded trees to 180 and 30 larvae per m^2, respectively. Defoliation exceeded 75% on unsprayed, unbanded trees and unbanded trees sprayed with soap, but remained below 25% on trees sprayed with B.t. or cyfluthrin. Trunk barriers reduced larval density and defoliation under all insecticide treatments and on unsprayed trees, but their effect was minimal on trees treated with B.t. or cyfluthrin. None of the treatments affected the total number of gypsy moth egg masses on treated trees. These results indicate that ground-based applications of both B.t. and cyfluthrin can provide good foliage protection, but that the use of trunk barriers with these treatments provides little or no added benefit. The soap, which is a contact insecticide, did not provide adequate foliage protection.

The gypsy moth, *Lymantria dispar,* is a serious pest of deciduous trees throughout its range, which in the United States presently extends from Maine to North Carolina and west to Michigan. Since 1980, over 54 million acres of hardwood forest have been defoliated, despite a $143.4 million public expenditure for gypsy moth suppression activities (8). The gypsy moth is also a key pest of hardwood trees in landscapes of the northeastern United States (11). Because of the proximity of the problem to a large segment of the public, and the high value of trees in the urban and residential landscape, the economic impact of the gypsy moth is considered greatest in the nonforest environment (1). For homeowners and land managers who are not able or willing to organize or participate in a community-wide aerial application program, ground-based pesticide applications may be the only practical and effective option available. Unfortunately, few studies of the efficacy of ground-based insecticide applications against the gypsy moth under operational conditions have been published.

Sticky trunk barriers are another management tactic available to homeowners for the protection of individual trees. This approach is attractive to homeowners because it is inexpensive and nontoxic, and can be applied without assistance by nonprofessionals to large trees in the ornamental landscape. Unfortunately, trunk barriers by themselves provide only limited reductions in larval density and defoliation and should not be relied upon to protect foliage (7). However, because sticky trunk barriers are highly effective at preventing larvae from ascending tree trunks (10), they may increase the effectiveness of treatments applied to individual trees by preventing reinfestation of the trees from adjacent trees. If so, the combination of ground-based insecticide applications to tree canopies and sticky trunk barriers might provide better control than either tactic by itself.

The objectives of this study were 1) to determine the comparative efficacy of insecticidal soap, *Bacillus thuringiensis* subsp. *kurstaki* (B.t.), and cyfluthrin when applied from the ground to individual oak trees and 2) to determine if the use of trunk barriers in combination with these treatments can increase their effectiveness.

Materials and Methods

The study was conducted in 1994 along 2 heavily wooded roads in Prince Georges County, Maryland. Gypsy moth egg mass density in the

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vicinity averaged 8,707 ± 3,988 (mean ± SE) per hectare (3,524 per acre) (4). Treatments and untreated controls were randomly assigned to white oak (*Quercus alba*) trees (mean dbh 34.1 ± 1.2 cm [13.3 in]) located within 20 m of the road. All trees were greater than 12 m (40 ft) in height. Treatments were originally grouped by proximity into 5 replicates. However, larval populations in 2 of the groups remained so low that they were dropped from the study. Only replicates with high gypsy moth populations that approximate those occurring in potentially defoliating gypsy moth populations were used. The soap (M-pede, Mycogen Corporation, San Diego, California), B.t. (Foray 48B, Novo Nordisk, Danbury, Connecticut) and cyfluthrin (Tempo 2, Mobay Corp., Kansas City, Missouri) were tank mixed on the day of application at rates of 7.6 L (2 gal), 2.8 L (0.7 gal) (36 BIU), and 30 mL (1 oz) per 379 L (100 gal) of water, respectively. A sticker (Bond, Loveland Industries, Greeley, Colorado) was added to the tank at a rate (v/v) of 2% (soap and B.t.) or 1.25% (cyfluthrin). The soap treatment, which kills by contact and has little or no residual activity, was not expected to benefit from the addition of the sticker and was added to this treatment so that it could be directly compared to the other treatments. The soap and B.t. were applied on May 2, and the cyfluthrin was applied on May 5, 1994, when larvae were predominantly in the second instar. All materials were applied to runoff, which required a volume of approximately 100–200 L (26–53 gal) per tree, using standard hydraulic application equipment at a pressure of 550 psi.

Each replicate of insecticide treatment or control consisted of 2 trees. One of these trees was treated with a sticky trunk barrier, and the bole of the other was left untreated. Trunk barriers were applied to boles prior to egg hatch by wrapping them with a band of duct tape (52 mm [2 in] wide) at a height of 1.5 m (4.8 ft), then applying by gloved hand a 10–20 mm (0.4–0.8 in) wide, 1–5 mm (0.04–0.2 in) thick band of Tanglefoot (The Tanglefoot Company, Grand Rapids, Michigan) to the center of each band of tape. Gaps between the tape and the tree were filled with a polyester fiber material (Poly-fil, Fairfield Processing, Danbury, Connecticut) to prevent larvae from passing beneath the barrier. The effectiveness of these barriers in preventing gypsy moth larvae from crossing was established by direct observation.

Egg masses on each tree were counted with the aid of binoculars before egg hatch and again after oviposition. Defoliation was subjectively estimated with the aid of binoculars in 10% increments on each of the trees after larval feeding had ended, but before refoliation occurred.

Larval population density was estimated for each tree using the frass drop/frass yield method (2,3). Frass falling from the canopy was sampled with 10 plastic buckets (21 cm diameter x 15 cm high [8.2 x 5.9 in]) per tree. The number of frass pellets falling into the buckets during a single 24-hour period was counted and used to estimate the amount of frass falling per m² of ground surface beneath the canopy. Frass yield (the amount of frass produced per larva during the sampling period) was determined by collecting 25–50 larvae from the study area and placing them individually in 177 mL (6 oz) plastic cups with cardboard lids. The cups were each provisioned with 1 or 2 oak leaves and were then left in a shaded area near the experimental trees. These larvae were removed from the cups at the same time that the frass samples were collected, 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 in each tree (number of larvae per m²) was estimated using the equation (3):

$$\textbf{Density} = C \cdot (x_d / x_y)$$

where C = 1/(area sampled by each bucket); x_d = mean drop (frass/bucket); x_y = mean yield (frass/larva). Samples were conducted at approximately 1, 3, and 4 weeks post-treatment.

Data were analyzed by analysis of variance (ANOVA) using the General Linear Models (GLM) procedure of the SAS statistics package (6). The data were analyzed as a split-plot design, with insecticide treatment as the mainplot factor, using the block by treatment interaction as the error term to test the significance of the treatment effect, and with the trunk barrier treatment as the subplot factor. When the treatment effect was significant, means were separated at a comparison-wise error rate of 0.05 using the least significant difference (LSD) procedure (6). When needed to stabilize the variance, the data were transformed to logarithms prior to analysis. Untransformed values and standard errors are reported in the tables.

Results

The combined effects of the insecticide treatments and the trunk barriers on estimated larval density in the canopy are shown in Figure 1 for 3 sample dates. On the first 2 sample dates, which occurred at approximately 1 and 3 weeks after treatment, both the insecticide and barrier treatment effects were significant (Table 1). On the third sample date, which occurred approximately 4 weeks after treatment, only the insecticide treatment effect was significant. The insecticide treatment by trunk barrier interaction effect was not significant on any of the sampling dates. On the first sampling date, larval density averaged approximately 500 per m² in unsprayed, unbanded trees and in unbanded trees treated with soap. The trunk barrier reduced larval densities to approximately 300 per m² in the unsprayed and soap-treated trees. Larval densities in unbanded trees treated with B.t. and cyfluthrin were reduced to approximately 180 and 30 larvae per m², respectively.

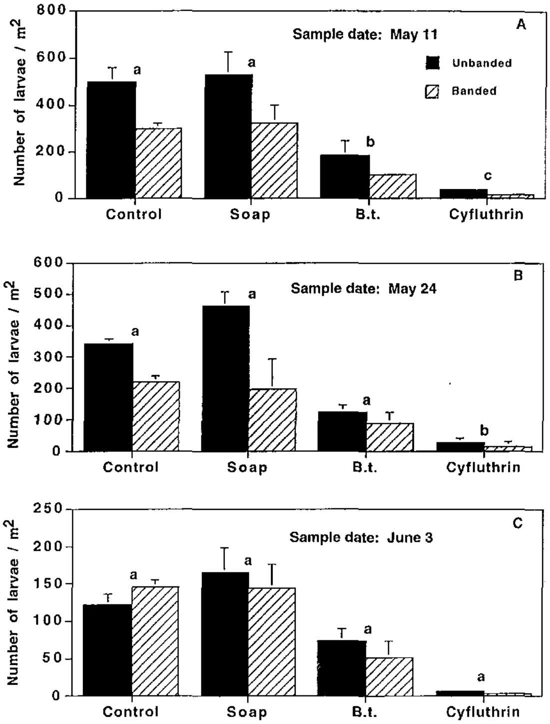

Figure 1. Larval density in oak trees under 4 insecticide treatments and with or without sticky trunk barriers. Samples occurred approximately 1, 3, and 4 weeks after insecticide treaments (A, B, and C, respectively). Insecticide treatments within each sampling date associated with the same letter are not significantly different at a 0.05 comparison-wise error rate.

Table 1. Analysis of variance of the effects of insecticide treatment and trunk barriers on gypsy moth larval density in oak canopies.

		May 11[a]		May 24[b]		June 3[b]	
Source	df	*F*	*P*	*F*	*P*	*F*	*P*
Insecticide	3	43.6	0.0002	15.1	0.003	32.0	0.0004
Barrier	1	10.5	0.01	18.1	0.003	2.9	0.1
Insecticide x barrier	3	0.5	0.7	0.9	0.5	1.4	0.3

[a]Data transformed to log (x + 100) prior to analysis.
[b]Data transformed to log (x + 1) prior to analysis.

On the second sampling date (approximately 3 weeks after insecticide treatment), larval densities in unsprayed, unbanded trees averaged 343 per m². This was not significantly different from trees treated with soap or B.t., in which larval density averaged 461 and 122 per m², respectively. Larval density under the cyfluthrin treatment averaged 26 per m², which was significantly lower than in the other treatments. The trunk barriers significantly reduced larval density in all insecticide treatments.

On the third sampling date (approximately 4 weeks after insecticide treatment), larval densities in unsprayed, unbanded trees averaged 122 per m². Only the cyfluthrin treatment was significantly lower, with larval densities that averaged 6 per m². By the third sample, larval density in the unbanded control trees appeared to have dropped below that in the banded control trees. This was probably due to the emigration of larvae from the untreated trees, which were experiencing severe defoliation by the time of this sample. Overall differences in larval density due to trunk barriers were not statistically significant at the time of the third sample.

The effects of the insecticide and barrier treatments on defoliation are shown in Figure 2. Significant differences in defoliation occurred among the insecticide treatments ($F = 26.5$; df = 3,6; $P = 0.0007$), with significantly less defoliation in the trees treated with B.t. (10%) and cyfluthrin (15%) than in trees that were unsprayed (75%) or sprayed with soap (75%). The effect of the trunk barriers was significant ($F = 8.9$; df = 1,8; $P = 0.02$), reducing defoliation from 49% to 38% overall. There was evidence of an interaction between insecticide treatment and trunk barrier; however, it was not significant at the 0.05 level ($F = 3.4$; df = 3,8; $P = 0.07$).

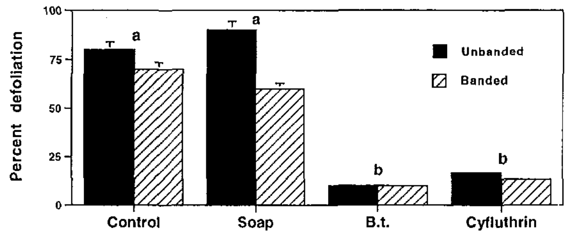

Figure 2. Defoliation of oak trees under 4 insecticide treatments and with or without sticky trunk barriers. Insecticide treatments within each sampling date associated with the same letter are not significantly different at a 0.05 comparison-wise error rate.

No significant differences in post-season egg mass numbers per tree occurred among any of the treatments ($F = 2.5$; df = 3,6; $P = 0.2$, $F < 0$; df = 3,6; $P > 0.99$, and $F = 0.6$; df = 3,8; $P = 0.6$ for the insecticide treatment, trunk barrier treatment, and interaction effect, respectively) (Table 2).

Discussion

While ground applications of both B.t. and cyfluthrin reduced larval population density in the canopy as compared to the control trees, the reduction was much more dramatic with cyfluthrin (93.8% reduction 1 week after treatment versus 63.2% reduction with B.t. on unbanded trees). This difference between the 2 insecticides persisted through the remainder of the larval period. Despite this difference in impact on larval density, both B.t. and cyfluthrin resulted in excellent foliage protection under high-density gypsy moth populations. The reasons for this apparent discrepancy are not clear. It is known that larvae poisoned by B.t. rapidly stop feeding but may take several days to die (9). However, frass production by infected larvae also rapidly ceases. In the present study larval density estimates were based on the quantity of frass produced by larvae feeding in the canopy. Therefore, assuming that at least some of the affected larvae eventually recovered, the frass method should have underestimated larval density, rather than overestimated it. Another possible explanation for the lack of agreement between the larval density and defoliation estimates in trees treated with B.t. is that larval density was reduced to sufficiently low levels to prevent substantial defoliation by the B.t. treatment, even though more larvae were present than in the cyfluthrin-treated trees.

Table 2. Number of gypsy moth egg masses on oak trees treated with ground-based insecticide applications and sticky trunk barriers.

Insecticide treatment	Trunk barrier	No. of egg masses per tree (pre-season)	No. of egg[a] masses per tree (post-season)
Control	Present	42.3 ± 32.3	30.0 ± 16.0
	Absent	16.0 ± 4.5	17.3 ± 9.1
Soap	Present	88.7 ± 41.1	59.3 ± 26.5
	Absent	112.0 ± 55.6	53.7 ± 25.8
B.t.	Present	28.7 ± 4.6	19.7 ± 2.4
	Absent	56.0 ± 42.5	31.3 ± 12.6
Cyfluthrin	Present	84.3 ± 34.0	52.0 ± 19.3
	Absent	122.0 ± 79.8	62.0 ± 59.3

Values are mean ± SEM. Result of analysis of variance given in text.
[a]Data transformed to ln (x + 100) prior to analysis.

Trunk barriers significantly reduced larval density and defoliation in the canopies of both sprayed and unsprayed trees. The probable presence of an insecticide treatment by trunk barrier interaction effect indicates that the impact of the trunk barriers was greater in some treatments than in others. It can be seen in Figure 2 that the trunk barriers had a greater effect on defoliation of untreated trees and trees treated with soap than in trees treated with B.t. and cyfluthrin. These results suggest that trunk barriers provide little or no additional benefit when combined with highly effective insecticide treatments. Trunk barriers appeared to have the greatest impact when used on trees treated with soap. However, even the combination of soap and trunk barriers did not provide adequate foliage protection. Soap is known to cause high levels (>85%) of mortality under controlled conditions with adequate coverage of larvae with the soap formulation (5). Therefore, the lack of effectiveness of the soap treatments in this study may be due to inadequate coverage of larvae in the canopy. Adequate control of gypsy moth larvae with hydraulic applications of soap has been reported on smaller oak trees (7.6–9.1 m [25–30 ft]) where good coverage was obtained (Lee Hellman, personal communication). Also, the lack of residual activity of the soap may have permitted some reinfestation of treated trees from the canopies of adjacent trees. The greater effect of the trunk barriers on trees treated with soap may indicate that the soap irritated the larvae and caused them to drop from the canopy, with the trunk barriers preventing their reascent.

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Literature Cited

1. Leuschner, W. A. 1994. Gypsy moth containment program: an economic assessment. Proc. U.S.D.A. Gypsy Moth Res. Forum. p. 36.
2. Liebhold, A. M., and J. S. Elkinton. 1988a. *Techniques for estimating the density of late-instar larval gypsy moth,* Lymantria dispar *(Lepidoptera: Lymantriidae), populations using frass drop and frass production measurements.* Environ. Entomol. 17: 381–384.
3. Liebhold, A. M., and J. S. Elkinton. 1988b. *Estimating the density of larval gypsy moth,* Lymantria dispar *(Lepidoptera: Lymantriidae), using frass drop and frass production measurements: sources of variation and sample size.* Environ. Entomol. 17: 385–390.
4. Liebhold, A., K. Thorpe, J. Ghent, and D. Barry Lyons. 1994. Gypsy moth egg mass sampling for decision-making: a users' guide. U.S.D.A., Forest Service, NA-TP-04-94.
5. Nielsen, D. G. 1990. *Evaluation of biorational pesticides for use in arboriculture.* J. Arboric. 16: 82–88.
6. SAS Institute. 1985. SAS User's Guide: Statistics, Version 5 Edition. Cary, N.C.
7. Thorpe, K. W., K. M. Tatman, P. Sellers, R. E. Webb, and R. L. Ridgway. 1995. *Management of gypsy moths using sticky trunk barriers and larval removal.* J. Arboric. 21: 69–76.
8. Twardus, D. B. 1994. Gypsy Moth News. 35: 1–14.
9. van Frankenhuyzen, K. and J. L. Gringorten. 1991. *Frass failure and pupation failure as quantal measurements of* Bacillus thuringiensis *toxicity to Lepidoptera.* J. Invert. Path. 58: 465–467.
10. Webb, R. E. and V. K. Boyd. 1983. *Evaluation of barrier bands and insecticidal strips for impeding intraplant movement of gypsy moth caterpillars.* Melsheimer Entomol. Ser. 33: 15–20.
11. Wu, Z., S. Jamieson, and J. Kielbaso. 1991. *Urban forest pest management.* J. Arboric. 17: 150–158.

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Zusammenfassung. An einzelnen Weißeichen (*Quercus alba*), die heftig von Schwammspinnern *(Lymantria dispar)* befallen waren, wurde die kombinierte Wirkung von Insektizidapplikationen durch hydraulische Geräte und Leimfallen um die Stämme getestet. Die getesteten Insektizide waren insektizide Schmierseife, *Bacillus thuringiensis* (B.t.) und Cyfluthrin. Eine Woche nach der Insektizid-Behandlung zeigten die B.t.- und Cyfluthrinversuche eine reduzierte Larvendichte von ursprünglich 500 Larven pro m" auf dem Boden zu 180 und 30 Larven pro m". Die Entlaubung betrug bis zu 75% auf ungespritzten, bandagierten und unbeandagierten, mit Seife behandelten Bäumen, aber blieb unter 25% bei Bäumen, die mit B.t. oder Cyfluthrin gespritzt waren. Die Leimbandagen reduzierten die Larvendichte und die Entlaubung während aller Insektizidangwendungen und auch auf ungespritzen Bäumen, aber ihre Wirkung war bei den Bäumen, die mit B.t. oder Cyfluthrin behandelt wurden minimal. Keine der Behandlungen konnte die totale Anzahl der Eigelege der Schwammspinner auf den behandelten Bäumen reduzieren.