MANAGEMENT OF GYPSY MOTHS USING STICKY TRUNK BARRIERS AND LARVAL REMOVAL

by Kevin W. Thorpe, Kathy M. Tatman[1], Patricia Sellers[2], Ralph E. Webb and Richard L. Ridgway

Abstract. The effects of sticky trunk barriers and the removal of gypsy moth, *Lymantria dispar,* larvae from burlap skirts positioned above the trunk barriers on larval density and defoliation in the canopy of oak trees was tested. Sticky barrier bands reduced larval gypsy moth density and defoliation by approximately 25 and 30%, respectively. An average of 9 and 26 larvae were removed from trees with one and four burlap skirts, respectively. There was no indication that larval removal affected larval density or damage in the canopies of treated trees. The use of barrier bands and burlaps resulted in a greater accumulation of gypsy moth pupae and egg masses on the lower 2 m of the boles of treated trees, making these life stages more accessible for later removal or treatment. None of the treatments affected the total number of gypsy moth egg masses on treated trees. These results suggest that sticky trunk barriers can provide some foliage protection, but that, because the amount of protection is relatively small, they should not be relied upon for protection from gypsy moth damage.

Key words. *Lymantria dispar,* mechanical control, trunk barriers, burlap

The gypsy moth, *Lymantria dispar,* is one of the most serious defoliators of hardwood trees in the northeastern United States. Unlike many other forest pests, gypsy moths also have great impact in suburban and residential areas, where they may cause widespread defoliation which can result in heavy tree mortality (4). Management tactics available to the homeowner include aerial or ground foliar insecticide applications and insecticidal implants or injections (17), usually done by professionals at the homeowner's expense. Management tactics that can be applied to large trees in the landscape directly by the homeowner include the application of sticky trunk barriers (16), the removal of larvae from beneath burlap bands (1), and the removal or treatment of egg masses (2, 18).

Sticky trunk barriers have been shown to restrict the movement of gypsy moth larvae up the boles of trees (16). The use of trunk barriers results in a measurable reduction in the number of larvae in the canopies of trees (13, 14, 15), and under certain conditions can reduce defoliation (1). Commercially-prepared barrier materials used against the gypsy moth (16) are widely available, and purchased or homemade trunk barriers are commonly employed by homeowners. A survey of homeowners in New Hampshire (9) found that 42% of those individuals that used control measures against the gypsy moth used sticky trunk barriers.

The removal of gypsy moth larvae from beneath burlap skirts that have been placed around the boles of trees is frequently mentioned as a management tactic available to the homeowner (8, 10). A survey by Miller and Lindsay (9) reported that 75% of respondents that used control measures against the gypsy moth used some form of manual destruction. Campbell (2) investigated the impact of this procedure and found it to be ineffective. However, in his study, sticky barriers were not employed, and larvae were free to move up the boles of the trees from the ground to the burlaps. It is known that gypsy moth larvae move from tree to tree along the ground and tend to accumulate in trees with burlap skirts (7). Therefore, an unknown, but potentially large, proportion of the larvae beneath burlap skirts in Campbell's study may have arrived from the ground, and their removal would not be expected to impact populations in the canopy. Thorpe et al. (14) monitored

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gypsy moth larvae beneath burlap bands that were placed on the boles of oak (*Quercus* spp.) trees above sticky trunk barriers, and found that the numbers of larvae beneath burlap above the trunk barriers was as much as five-fold lower than the numbers of larvae beneath burlap when there were no trunk barriers.

The objectives of this study were to determine the impact of sticky trunk barriers on gypsy moth larval density and oak canopy damage under a range of population densities and to determine if the removal of larvae from beneath burlap skirts positioned above the trunk barriers can enhance the impact of the trunk barriers. A treatment with multiple burlap skirts was included to determine if it increased the number of larvae that could be removed.

Materials and Methods

The study was conducted in 1993 at forested sites near Harrisonburg, VA, Pomona, MD, and Vienna, MD. The mean bole diameters and mean dripline areas of the experimental trees at each site are given in Table 1. At least 80% of the trees used in the study at each site were white oak (*Q. alba*). Preseason egg-mass densities varied from about 4,000 per hectare at the Pomona site to over 16,000 per hectare at the Harrisonburg site. Ten groups of four oak trees at both the Pomona and Vienna sites, and six groups of four oak trees at the Harrisonburg site, were selected to serve as replicates. The canopies of all trees in the experiment were touching those of adjacent trees. Each of the four trees within a group received a different treatment. The four treatments were 1) sticky trunk barrier, 2) sticky trunk barrier + burlap skirt, 3) sticky trunk barrier + four burlap skirts, and 4) untreated control. Prior to egg hatch, sticky barriers were applied to tree trunks by wrapping them with duct tape (52 mm wide), then applying by gloved hand a 10-20 mm wide, 1-5 mm thick band of Tanglefoot™ (The Tanglefoot Company, Grand Rapids, MI) to the center of each band of tape. Small gaps between the tape and the tree were filled with Poly-fil™ polyester fiber (Fairfield Processing Corp., Danbury, CT) to prevent larvae from passing beneath the barrier. The effectiveness of these barriers in preventing gypsy moth larvae from crossing was confirmed by direct observation throughout the study. For treatments 1 and 2, the trunk barrier was applied to the bole at a height of approximately 1.5 m.

For treatment 2, a burlap skirt (40 cm wide) was folded in half lengthwise and wrapped around the bole 1-2 cm above the trunk barrier. For treatment 3, the trunk barrier was applied to the bole at a height of approximately 0.5 m, and four burlap skirts were applied to the bole above the trunk barrier. Each burlap was positioned 1-2 cm above the trunk barrier or burlap directly below it.

On each of 4 (Pomona and Vienna) or 6 (Harrisonburg) dates, all larvae beneath the burlap skirts were counted, removed, and destroyed. After the completion of adult eclosion, the number of pupae and new egg masses was determined for each burlap. On all trees, the number of pupae and egg masses on the lower 2 m of bole was recorded. Defoliation was estimated subjectively with the aid of binoculars in 10% increments on each of the experimental trees by a single experienced worker after larval feeding had ended but before refoliation occurred.

Egg masses on the upper bole and canopy of each experimental tree were counted with the aid of binoculars before egg hatch and again after oviposition. The egg-mass density at each site was estimated from ten 0.01 ha (1/40th acre) egg-mass surveys, using the procedures described by Kolodny-Hirsch (3).

Larval population density prior to the onset of pupation was estimated for each tree using the frass drop/frass yield method (5, 6). Frass falling from the canopy was sampled with ten plastic buckets (20.0 cm diameter x 15.5 cm high) posi-

Table 1. Diameter and canopy area of experimental oak trees and preseason gypsy moth egg-mass density at three sites in Maryland and Virginia.

Site	Mean bole[a] diameter (cm)	Mean dripline area (m^2)	Preseason egg masses per ha
Harrisonburg, VA	38.7 ± 1.4	54.9 ± 6.3	16,275 ± 2,957
Pomona, MD	41.0 ± 1.2	58.5 ± 3.9	3,973 ± 963
Vienna, MD	36.2 ± 1.5	77.7 ± 6.6	9,806 ± 3,092

Values reported are mean ± SEM
a. Diameter measured at a height of 1.5 m.

tioned in random locations beneath the canopy of each experimental tree. The frass was collected from the buckets approximately 24 h after they were placed beneath the trees. The number of frass pellets falling into the buckets was counted and used to estimate 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 50 larvae from each site at the same time that frass drop was sampled, 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 set in an area near the experimental trees but protected from the sun. These larvae were removed from the cups at the same time that the frass was 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 the canopy of each tree (number of larvae per m^2 of ground surface) was estimated using the equation (6):

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

where C = 1/(area sampled by each bucket);
x_d = mean drop (frass/bucket);
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. Samples were conducted at the Pomona and Harrisonburg sites on June 10, when larvae were predominantly in the fifth instar. Because of the extremely high gypsy moth population density at the Vienna site, the frass sample was conducted on May 25, when larvae were predominantly in the fourth instar. This was necessary to avoid sampling trees that had already received greater than 50% defoliation.

Treatment effects were analyzed by analysis of variance (ANOVA) using the GLM procedure of the SAS statistics package (11). The data were analyzed as a split-plot design, with site as the mainplot factor, using groups within sites as the error term to test the significance of the site effect, and with trunk barrier/burlap treatment as the subplot factor. The site x treatment interaction effect was tested for each variable to determine the appropriateness of combining the three sites into a single analysis. Functional relationships between selected variables were tested using the REG procedure of the SAS statistics package (11). When needed to stabilize the variance, the data were transformed to logarithms prior to analysis.

Results

Gypsy moth population density varied among the three sites (Table 2). Larval density was low to moderate at the Pomona and Harrisonburg sites

Table 2. Estimated number of gypsy moth larvae and defoliation on oak trees treated with trunk barriers and burlap skirts.

Site	Number of larvae removed per tree [a,b]	Number of larvae per m^2 [c]	Number of larvae per tree [c]	Defoliation [b]
Harrisonburg	35.4 ± 4.0 a	94.1 ± 21.5 a	4,780 ± 2,041 a	14.8 ± 5.7 a
Pomona	11.2 ± 3.1 a	83.9 ± 16.7 a	4,908 ± 1,581 a	20.8 ± 4.4 b
Vienna	5.7 ± 3.1 a	215.0 ± 17.0 b	17,238 ± 1,610 b	68.4 ± 4.4 c

Values reported are mean ± SEM. Means within a column followed by the same letter are not significantly different at a 0.05 comparison-wise error rate.
a. Includes only trees with burlap skirts.
b. Data transformed to ln (x + 10) prior to analysis.
c. Data transformed to ln (x) prior to analysis.

Table 3. Estimated number of gypsy moth larvae and defoliation on oak trees treated with trunk barriers and burlap skirts.

Treatment	Number of larvae removed per tree	Estimated number of larvae per m^2 [a]	Estimated number of larvae per tree [a]	Defoliation [b]
Control	0	161.5 a	7,943 a	33.7 a
Trunk barrier	0	126.5 b	5,888 ab	23.1 b
Barrier + 1 burlap	9.0	103.3 c	4,169 b	22.4 b
Barrier + 4 burlaps	25.8	132.6 b	6,457 a	25.5 b
	(SEM = 2.8)	(SEM = 10.9)	(SEM = 1,757)	(SEM = 3.0)

Means within a column followed by the same letter are not significantly different at a 0.05 comparison-wise error rate. SEM, standard error of the mean.

a. Data transformed to ln (x) prior to analysis.

b. Date transformed to ln (x + 10) prior to analysis.

(94.1 and 83.9 larvae per square meter of canopy, respectively) and high at the Vienna site (215.0 larvae per square meter of canopy) (F = 19.6; df = 2,23; P < 0.0001). Average number of larvae per tree ranged from 4,780 at the Harrisonburg site to 17,238 at the Vienna site (F = 17.4; df = 2,23; P < 0.0001). Defoliation was low at the Harrisonburg and Pomona sites (14.8 and 20.8%, respectively), and high (68.4%) at the Vienna site (F = 93.4; df = 2,23; P < 0.0001). The average number of larvae per tree removed from the burlap skirts above the sticky barrier bands varied from 5.7 at the Vienna site to 35.4 at the Harrisonburg site (F = 34.3; df = 2,23; P = 0.03).

For all variables measured, the site x treatment interaction was either non-significant, or if it was significant, then the ordering of the treatment means was consistent for all sites. Therefore, data from the three sites were combined to show the overall effects of the treatments (Table 3). The number of gypsy moth larvae beneath the burlap bands on any given date ranged from 0 to 49 on trees with a single burlap and from 1 to 109 on trees with four burlaps. On average, a total of 9 and 25.8 larvae per tree were removed from trees with single and multiple burlaps, respectively (F = 20.2; df = 1,23; P = 0.0002). A regression analysis indicated that there was no relationship between the density of larvae in the canopy and the number of larvae removed from under burlap (F < 0.01; df = 1,50; P = 0.99; R^2 < 0.01).

The estimated average number of larvae per square meter of canopy differed significantly among the treatments (F = 7.3; df = 3,68; P = 0.0003). Density was highest in the untreated trees (161.5 per m^2) and ranged from 103.3 to 126.5 per m^2 among the trees treated with sticky trunk barriers. Density was significantly lower on trees with the trunk barrier + single burlap treatment. The estimated average number of larvae per tree also differed significantly among treatments (F = 5.0; df = 3,68; P = 0.003), and varied from 4,169 for trees with the trunk barrier + single burlap treatment to 7,943 for untreated trees. Because of the greater variability in these estimates, the trunk barrier alone and the trunk barrier + multiple burlaps treatments were not significantly different from the untreated trees. Defoliation was significantly lower in trees with sticky trunk barriers, but there were no differences among the treatments with trunk barriers (F = 3.8; df = 3,69; P = 0.01).

The number of gypsy moth pupae and egg masses on the lower 2 m of the boles of untreated trees averaged 9.6 and 36.5, respectively (Table 4). On trees with sticky trunk barriers but no burlap skirts, there were an average of 39.2 pupae and 48.8 egg masses. On trees with a trunk barrier and one burlap there were an average of 64.9 pupae and 59.2 egg masses. On trees with a trunk barrier and four burlaps there were an average of 143.7 pupae and 90.5 egg masses. Significant differ-

Table 4. Number of gypsy moth pupae and egg masses on oak trees treated with trunk barriers and burlap skirts.

Treatment	Number of pupae below 2 m[a]	Number of egg masses below 2 m[b]	Number of egg masses per tree Preseason [b]	Number of egg masses per tree Postseason [c]	Egg mass trend (Post/pre-season)
Control	9.6 a	36.5 a	45.1 a	235.9 a	5.2
Trunk barrier	39.2 b	48.8 a	34.8 a	168.3 a	4.8
Barrier + 1 burlap	64.9 c	59.2 b	31.5 a	145.9 a	4.6
Barrier + 4 burlaps	143.7 d	90.5 c	39.8 a	211.0 a	5.3
	(SEM = 13.2)	(SEM = 16.6)	(SEM= 6.0)	(SEM = 53.6)	

Means within a column followed by the same letter are significantly different at a 0.05 comparison-wise error rate. SEM, standard error of the mean.
a. Data transformed to ln (x + 5) prior to analysis.
b. Data transformed to ln (x) prior to analysis.
c. Data transformed to ln (x + 1) prior to analysis

ences occurred among the treatments for both numbers of pupae (F= 55.9; df = 3,60; P< 0.0001) and egg masses below 2 m (F= 46.4; df = 3,56; P < 0.0001).

The total number of postseason egg masses per tree ranged from 145.9 on trees with a trunk barrier and one burlap to 235.9 on untreated trees (Table 4). However, the means for the treatments were not significantly different (F= 1.9; df = 3,60; P= 0.14). The number of egg masses on all trees, regardless of treatment, increased by approximately 5-fold.

The functional relationship between gypsy moth larval density in the canopy of individual trees and percent defoliation is shown in Figure 1. The relationship is non-linear, so a polynomial model

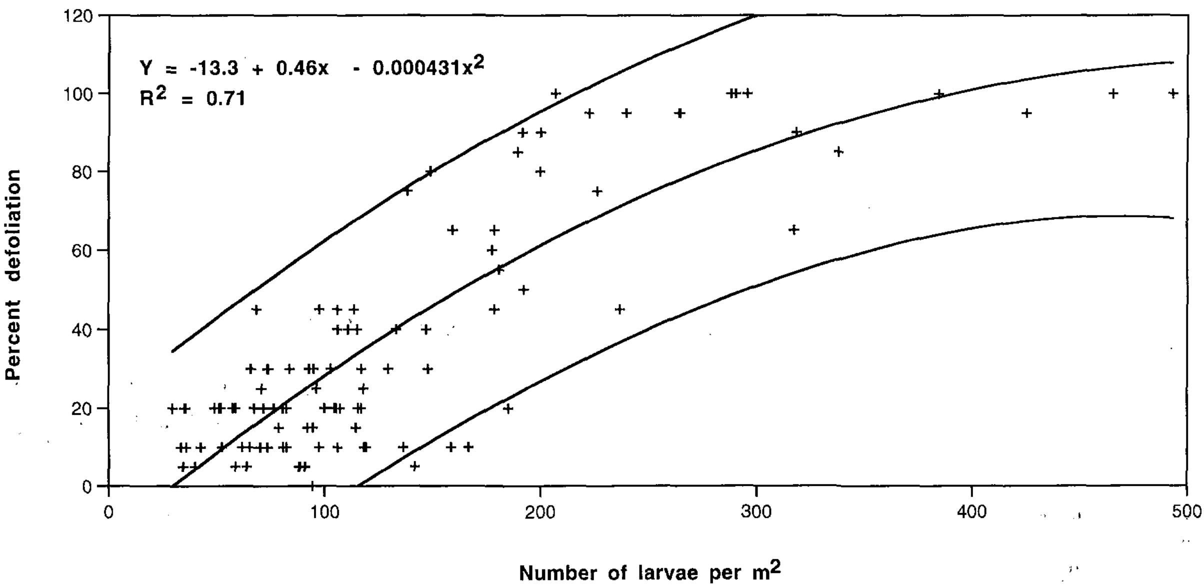

Figure 1. Relationship between gypsy moth larval density and defoliation in the canopies of individual oak trees. The center line indicates predicted values and the outer lines indicate 95% prediction intervals.

was fit to the data (F = 121.2; df = 2,100; P < 0.0001; R^2 = 0.70).

Discussion

Despite the wide range of gypsy moth larval densities encountered in this study, the number of gypsy moth larvae available for removal from beneath burlap skirts was very low at each of the sites. While more frequent and persistent collection of larvae would probably have resulted in higher numbers removed, it is unlikely that enough larvae could be removed in this way to impact population density in the tree canopy. For example, based on the average number of larvae per tree (Table 2), to reduce larval density by 10% would require the removal of an average of 478, 491, or 1,724 larvae per tree from the trees at the Harrisonburg, Pomona, and Vienna sites, respectively. Given the low numbers of larvae found beneath the burlap skirts, the removal of this many larvae would not be possible. Thorpe et al. (14) found a similarly low number of larvae beneath burlap skirts positioned above sticky trunk barriers relative to larval density in the canopy. However, in a 1988 study, Webb et al. (unpublished data) report the removal of over 4,000 larvae from beneath burlap bands positioned above sticky trunk barriers. It is likely that the number of larvae that can be removed in this way is highly variable and unpredictable, but that under certain circumstances it may be possible to remove significant numbers of larvae from the tree canopy. It should be noted that much greater numbers of larvae would be expected to occur beneath burlap skirts in the absence of trunk barriers. However, the source of most of these larvae would be from the ground. Since there is no barrier to invasion of the canopy by additional larvae, the removal of larvae from burlaps in the absence of trunk barriers is unlikely to impact canopy density.

Larval density in the canopy of trees with a sticky trunk barrier plus one burlap skirt was significantly lower than in trees with four or no burlaps. Since the average number of larvae removed was lower on trees with one burlap than on trees with four burlaps, and since the number removed was less than 1% of the total number of larvae per tree, it is unlikely that the reduced density of larvae in the canopy resulted from larval removal. Also, given the low rate of visitation of burlap by larvae, it is unlikely that increased mortality of larvae beneath the burlap skirt was the cause of the reduction in density. Therefore, it seems probable that this apparent difference between these treatments is a statistical artifact.

The sticky barrier bands reduced larval density in the canopy by an average of 25%. The magnitude of this effect is very similar to that seen in our previous studies (27% [13], 35% [14], 28% [15]). In the Thorpe et al. (15) study the gypsy moth population was too low to cause measurable defoliation. In the Thorpe et al. (14) and Thorpe and Ridgway (13) studies, defoliation was reduced by sticky trunk barriers 25 and 28%, respectively, but neither of these reductions was statistically significant. In the present study, defoliation was reduced 30% by trunk barriers, and this was a statistically significant reduction (Table 3). If the defoliation reduction results of Thorpe and Ridgway (13), Thorpe et al. (15), and this study are combined into a single statistical test (12), the effect is significant (x^2 = 22.5; df = 6; P = 0.001). Therefore, while the effect of sticky trunk barriers on foliage protection is small, it does appear to be a consistent and experimentally reproducible effect.

While the sticky trunk barriers had no effect on the total numbers of egg masses in treated trees, the treatments did affect the number of pupae and egg masses deposited on the lower 2 m of the bole. This may have practical significance for homeowners who want to remove and destroy gypsy moth pupae and egg masses from the portions of their trees that they can easily reach. The combined use of sticky trunk barriers and burlap skirts provided the highest number of pupae and egg masses on the lower 2 m of bole. The number was increased by using multiple burlaps. However, according to a study employing this technique (2), the removal of pupae and egg masses from the lower boles of trees did not affect subsequent local populations.

The use of sticky trunk barriers has been shown to reduce the density of gypsy moth larvae in the canopy by approximately 25-35%. While the degree of foliage protection achieved through this reduction in larval density is more variable, it appears to average approximately 25-30%. The experiments upon which these values are based were conducted over a range of population densities, with both closed-canopy and isolated oak trees, yet the results were consistent. Therefore, it appears that sticky trunk barriers can provide homeowners with a low-cost method to reduce gypsy moth density in the canopy of protected oak trees and to provide some foliage protection. However, the amount of protection is relatively small, and trunk barriers alone should not be relied upon to adequately protect trees from gypsy moth defoliation.

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Résumé. Les pièges faits de substances collantes ont permis de réduire les populations de spongieuse et, par le fait même, le degré de défoliation des chênes par des taux de 25 et 30% respectivement. Des nombres de 9 et de 26 larves étaient retirées d'arbres dont le tronc était entouré de une et de quatre enveloppes collantes, respectivement. Il y avait aucune indication particulière que le piégeage de larves affectait le nombre de larves retrouvées sur les arbres traités ou encore le degré de dommages dans la cime. L'utilisation de bandes ou d'enveloppes collantes conduisait à une plus forte accumulation de pupes de spongieuses et de masses d'œufs sur les deux mètres inférieurs du tronc des arbres traités. Aucun des traitements affectait le nombre total de masses d'œufs présentes sur les arbres traités. Ces résultats suggéreraient que la présence de barrières collantes sur les troncs d'arbres permet de fournir une certaine protection au feuillage; mais parce que le degré réel de protection est faible, il ne faut donc pas s'attacher à cette seule méthode pour le contrôle des dommages causés par la spongieuses sur les chênes.

Zusammenfassung. Leimringe reduzierten die Anzahl von Schwammspinnerraupen und die Entlaubung von Eichen um 25 und 30%. Es wurde auf Bäumen mit einem und vier Leimringen ein Durchschnitt von 9 und 26 Raupen entfernt. Es gab keine Anzeichen, daß das Entfernen der Raupen die Dichte der Raupen oder den Schaden an den Blättern beeinflusste. Die Anwendung von Leimringen führte dazu, daß in den unteren 2 m stamm eine Akkumulation von Schwammspinnern und ihren Eigelagen auftrat. Die gesamte Zahl der Schwammspinnereigelage wurde durch keine Behandlung beeinflußt. Diese Versuchsergebnisse lassen darauf schließen, daß Leimringe zwar einen gewissen Schutz des Laubes bieten, aber daß der Schutz relativ gering ist. Es sollte sich daher bei ihrem Gebrauch nicht auf den Schutz vor Schwammspinnerschaden verlassen werden.