Efficacy and Costs Associated with the Manual Removal of Bagworms, *Thyridopteryx ephemeraeformis*, from Leyland Cypress[1]

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Abstract

Bagworms (*Thyridopteryx ephemeraeformis*) are a common pest of landscape plants. The efficacy and costs were determined for the manual removal (handpicking) of bagworms from a single Leyland cypress (*X Cupressocyparis leylandii*) and estimated for a planting of 40 trees. Manual removal costs were compared to the estimated costs of spraying trees with the insect growth regulator tebufenozide. Handpicking the bags provided 92% control and required 160 minutes for one tree and an estimated 6,400 minutes for 40 trees. Labor costs for manual removal were estimated at $44 for one tree and $1764 for 40 trees. Estimated time required to spray a single tree was 71 minutes while 40 trees required an estimated 251 minutes. Estimated cost to spray one tree was about $28 and the cost for 40 trees was estimated to be $105. The time spent and costs of control are similar for handpicking and spraying single trees. Handpicking may be acceptable on single or small numbers of short trees that may be safely handpicked. However, as the number of trees increases, time and costs associated with handpicking increase dramatically, while costs to spray increase only slightly.

Index words: non-chemical control, Integrated Pest Management, mechanical control, School IPM.

Species used in this study: bagworm, *Thyridopteryx ephemeraeformis* (Haworth); Leyland cypress, *X Cupressocyparis leylandii.*

Significance to the Nursery Industry

Bagworms are important pests of plants in nurseries and landscapes. In sensitive environments, such as schools, manual removal of bagworms may be recommended or mandated. Growers of ornamental plants may consider manual removal of bagworms as an alternative to insecticide sprays. This study determined the effectiveness and costs associated with handpicking bagworms from Leyland cypress. Handpicking provided 92% control. The estimated cost to hand pick one tree was $44 and over $1700 for 40 trees. The estimated cost to spray the trees with the insect growth regulator tebufenozide was $28 for one tree and $105 for forty trees. At low population levels or if only a few plants are affected, handpicking may be a viable option for bagworm control. However, if many plants require treatment, handpicking may be more than ten times as expensive. This study provides information to green industry professionals to make sound pest management decisions.

Introduction

The bagworm, *Thyridopteryx ephemeraeformis* (Haworth), is a widespread defoliator of landscape plants. It is listed as one of the top ten pests of urban forests in the northeast and southern United States (26). Bagworms feed primarily on the foliage of evergreens, but it will also use deciduous trees as hosts (9, 10, 16). Bagworms seriously damage conifers in landscapes thereby reducing their aesthetic value (21). In nurseries, even small amounts of bagworm damage have been shown to significantly reduce consumer acceptance of American arborvitae, *Thuja occidentalis* (22). For landscape plants, Sadof and Raupp (23) suggested that the public has a similarly low tolerance for disfigurement of woody plants. In their review of nursery and landscape systems defoliation approaching 10% was noticed by observers and elicited a response for corrective actions. Using small evergreens, Raupp et al. (21) determined that as few as nine first instar bagworm larvae could create damage that would prompt most consumers to initiate control.

In the Mid-Atlantic region bagworms overwinter as eggs and emerge in late May through early June. Upon emergence, larvae begin to feed and construct their protective bags from silk and bits of plant material gathered from their host tree. As the season progresses, the larva grows and increases the size of its bag. When it reaches 30–50 mm (1.2–2.0 in) in length, the larva pupates within the bag. In early fall, the male emerges and seeks out flightless females. After mating, the female lays up to 1000 eggs in her bag (16, 17).

There are numerous insecticides labeled for the control of bagworms. These include synthetic pesticides such as acephate, carbaryl, and permethrin. With increasing adoption of IPM approaches in the urban landscape and nurseries, uses of bio-pesticides as well as biological and mechanical controls have been implemented more frequently. The biorational insecticide spinosad (Conserve®) and the insect growth regulator tebufenozide (Confirm®) have been shown to be effective at controlling bagworms (13). These products have been shown to have little or no affect on non-target predators and parasitoids (3, 24, 25). *Bacillus thuringensis* var. Kurstaki and the entomopathogenic nematode *Steinernema carpocapsae* have been used as effective biological control agents when applied to early instar larvae (2, 12).

Many publications recommend the manual removal of bagworms from trees as an alternative to spraying with in-

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secticides (9, 20). In some environmentally sensitive landscapes, such as schools, it may be preferable or mandated to employ mechanical control in lieu of chemical control. However, there are no published accounts of the efficacy and cost effectiveness of this approach in a managed landscape setting. In this study, we endeavor to determine the efficacy, as well as the costs, of handpicking bagworms from landscape trees.

Materials and Methods

Manual removal. A planting of Leyland cypress (*X Cupressocyparis leylandii*) heavily infested with bagworm larvae was used for the manual removal study. The site was located at Fulton Elementary School in Howard County, Maryland. Seven trees, approximately 7 m (23 ft) in height were used in this study. Three were assigned to the manual removal treatment and four served as untreated controls. Prior to the removal of bagworms, the surface area of each tree was estimated by assuming it was a right circular cone and computing the area as

$$S = (pi)r\sqrt{r^2 + h^2}$$

where S = surface area, r = radius, h = height. Following larval feeding in late August of 2003, bagworm abundance was estimated on each tree. A 0.37 m^2 (4 ft^2) frame was held at breast height at the cardinal and primary intercardinal points (8 points total per tree) and the number of bags visible within the frame was counted. The following day three workers removed as many bagworms as possible by handpicking them from the designated trees. The amount of time (worker minutes) required to pick bagworms from each tree was recorded. Prior to egg hatch in April of 2004, using the same methods described previously, bagworm densities were again estimated on each tree. The change in bagworm abundance, expressed as a percent change in the density of bagworms, was compared for non-treated and treated (handpicked) trees. Student's t-test was used to test for a difference between the two treatments (27). Data was transformed using Zar's modification of the Freeman and Tukey transformation (27) to meet the assumptions of the t-test. Untransformed means ±1 standard error are presented throughout.

Cost analysis. As this work was part of a study on the implementation of an IPM program in a public school system, labor costs were calculated using the grade and wage scale for the public school system. Costs for the manual removal of bagworms included the labor costs only for the removal of the bagworms. These costs were estimated for one tree and then multiplied by 40 to estimate the costs of treating 40 specimen trees located at the same site. These costs were compared to the costs of treatments with the insecticide tebufenozide (Confirm®). Cost of the insecticide treatment was calculated as the sum of the materials and labor. Labor costs included preparation for the treatment, posting, cleanup and reporting associated with the pesticide application. Pesticide applicators vary in their abilities to complete all steps necessary to conduct pesticide applications. Therefore, we obtained estimates of the amount of time required to treat trees for bagworms by surveying pesticide applicators in charge of pest management at four public institutions, Howard County Public Schools, University of Maryland, United States National Arboretum, and Smithsonian Institution. They were asked to estimate the time required to prepare the chemicals and equipment, spray, post signs, cleanup and complete any necessary paperwork for applications to control bagworms on one and 40, 7 m (23 ft), Leyland cypress trees. The costs of the materials involved in the application were obtained from the Howard County Public School system. Equipment costs, costs of pesticide applicator certification, and other miscellaneous costs were negligible and not included in either of the cost estimates.

Bagworm control costs for one tree and 40 trees using a conventional insecticide or hand removal were compared using a Student's t-test (27). Data for 40 trees was log transformed to meet the assumptions of the t-test. Untransformed means ±1 standard error are presented.

Table 1. Efficacy of manual removal of bagworms from Leyland cypress.

	Bags/m^2		
	August 2003	April 2004	Reduction (%)
Manual removal	16.9 ± 2.8[z]	1.2 ± 0.3	92.0%
Control	56.9 ± 13.2	27.6 ± 8.3	50.8%

[z]Bagworm densities are means ± SEM.

Results and Discussion

Efficacy of manual removal. In August of 2003, prior to handpicking, trees in the group slated for manual removal had a bagworm density of 16.9 ± 2.8 bags/m^2 (1.6 ± 0.4 bags/ft^2) and control trees had a bagworm density of 56.9 ± 13.2 bags/m^2 (5.3 ± 2.5 bags/ft^2). In April of 2004, trees that were handpicked harbored 1.2 ± 0.3 bags/m^2 (0.1 ± 0.05 bags/ft^2) and control trees contained 27.6 ± 8.3 bags/m^2 (2.6 ± 1.5 bags/ft^2). Manual removal in concert with natural destruction of bagworms provided a 92 ± 2% reduction in bagworm density. Trees that were not subjected to handpicking experienced a 51 ± 11% decrease in bagworm density between August and April (Table 1). The level of decline on handpicked trees was significantly different from that observed on trees where bagworms disappeared by natural causes alone ($P < 0.05$). Manual removal provided a level of control (92%) similar to that reported previously for chemical and biological control agents (Table 2). Tebufenozide and spinosad provided 95–100% control of bagworms in a nursery setting (14). When applied to early instar larvae, *Bacillus thuringensis* var. Kurstaki provided 77–100% control (2, 12).

In August 2003 when bagworms were removed by hand, care was taken to remove all bagworms. The fact that a residual, low density of bagworms was found the following

Table 2. Comparison of published efficacies of products labeled for control of bagworm.

Treatment	Control (%)	Reference
B.t. var. Kurstaki	77–100	2, 12
Steinernema carpocapsae	91–100	12
Acephate	86–100	6–8, 12
Carbaryl	70–95	12, 13, 19
Cyflurthrin	100	12
Permethrin	100	19
Spinosad	98–100	13
Tebufenozide	95–100	13
Trichlorfon	95	19

Table 3. Summary of costs for manual removal and spraying of bagworms on Leyland cypress.

	One tree			Forty trees		
Tactic	Labor cost	Material cost	Total cost	Labor cost	Material cost	Total cost
Removal	$44.11 ± 3.18	$0.00	$44.11 ± 3.18[z]	$1,764.27 ± 127.32	$0.00	1,764.27 ± 127.32[z]
Spray	$26.13 ± 6.10	$1.62	$27.75 ± 6.10	$92.13 ± 18.70	$12.87	$105.00 ± 18.70

[z]Total costs differed significantly between manual removal and spaying using a T-Test (p < 0.01). Data for one tree were not transformed. Data for 40 trees were log transformed prior to the analysis.

spring is indicative of two factors operating singly or in concert. First, it is possible that despite our attempts to completely remove bagworms, workers failed to detect all insects on the trees. Second, although hand removal was delayed until bagworm feeding appeared to have ceased, it is possible that late instar larvae colonized the hand picked trees from nearby untreated trees in late August or September after the manipulation had taken place. Late instar bagworms are known to emigrate from poor quality hosts (4). Although none of the non-treated Leyland cypress experienced high levels of defoliation, it is possible that some larvae may have moved from trees with higher bagworm densities to trees with lower ones later in the season.

Population reduction on the control trees was consistent with previous reports of natural populations. Berisford et al. (1) reported that 43–71% of larvae were killed by natural causes in a Georgia study. Ghent (11) reported that in a forest setting, 50% of the bagworms were destroyed between autumn and the following spring. Parasitism, particularly by the hymenopteran *Itoplectis conquistor* (Say), was the most commonly reported natural cause of bagworm death (5). Though parasitism can eventually control a bagworm population, bagworms often reach seriously damaging levels before this occurs (16). Other predators of bagworms include fungi (1), birds (11, 15, 18), and mammals (11).

Cost comparisons. As a means of comparison, average hourly wages for laborers and spray technicians were used in the cost calculations. The salaries for these positions are $16.54/hr and $22.00/hr, respectively. The cost to hand pick bagworms from a tree was calculated using the laborer salary rate. Manual removal of bagworms averaged (± S.E.) 160 (± 12) minutes per tree. The average cost to pick one tree was $44.11 (± $3.18). The estimated time and cost to handpick 40 trees were 6402 (± 462) minutes and $1,764.00 ± ($127.33), respectively.

The cost to spray trees was based on the use of the insect growth regulator tebufenozide (Confirm®), mixed with Latron-B® 1566, a spreader sticker, according to manufacturer guidelines. The bulk costs of the chemicals were $45.00/gal and $29.00/gal, respectively. The cost of insecticide and adjuvant to treat a single tree was estimated to be $1.62, and for 40 trees, $12.87.

The salary for a spray technician was used to determine the labor costs for the pesticide preparation, application, posting, cleanup, and paperwork. The time required for 1) setting up and cleaning the spray equipment, 2) posting, and 3) paperwork was similar for one tree, 51.3 (± 5.2) minutes, and 40 trees, 67.5 (± 7.5) minutes. The estimated time required to spray one tree was 20.0 (± 13.4) minutes and 183.8 (± 56.3) minutes for 40 trees. The total labor time for one tree was 71.3 (± 16.6) minutes and for 40 trees it was 251.3 (± 51.0) minutes. The estimated costs to spray one and 40 trees were $27.75 (± $6.10) and $105.00 (± $18.70), respectively.

Total costs to hand remove bagworms from a single tree or from 40 trees differed significantly from the cost to treat them with insecticides ($P < 0.01$) (Table 3). The magnitude of this difference increased dramatically with the number of trees treated. For a single tree the cost of hand removal was only approximately 1.6 times greater than for an insecticide spray. However, for 40 trees the cost of hand removal was about 16.8 times that of an insecticide spray. Spraying one or many trees at the same location required a relatively small increase in time because most of the time is spent preparing for and cleaning up from the application. Whereas, the hand removal of bagworms required a large and unchanging amount time for each tree irrespective of the number of trees treated.

Manual removal proved to be an effective tactic for controlling bagworms. When the infested trees are small enough to safely handpick, this may be a viable solution. The costs of control must be considered as well. If there are a small number of trees, or if they are only lightly infested, there is likely to be little difference in the costs of control between handpicking and insecticide sprays. As the number of trees requiring treatment increases, the costs for handpicking escalate, while the cost of spraying increases only slightly (Table 3).

If plant managers desire or are mandated to use alternative tactics to insecticides, such as the manual removal of bagworms, they must be prepared to allocate more money to these efforts. Labor costs will be great because these tactics are labor intensive. It is with these tradeoffs in mind that landscape managers must decide on the management tactics appropriate for their situation.

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