Strategies for Managing Hemlock Woolly Adelgid (*Adelges tsugae*) in Forests

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Abstract

Hemlock woolly adelgid (*Adelges tsugae*) is a severe pest of the eastern hemlock (*Tsugae canadensis*) and Carolina hemlock (*Tsuga caroliniana*). There is no reported resistance at any life cycle stage for either tree species. Eliminating pests from hemlock requires application of treatments to individual trees; therefore, many forest managers have not considered the eradication of hemlock woolly adelgid in forests an option. We report how the hope for an effective biological control combined with the implementation of a program of evaluation, treatment, management, and monitoring has become an acceptable option for forest landowners in northeastern Pennsylvania and southern New York.

Keywords:

Control, *Pseudoscymnus tsugae*, management strategies.

Introduction

The hemlock woolly adelgid (*Adelges tsugae*) was first reported in the Unites States near Richmond, Virginia in the mid 1950's (McClure 1987). It spread northward into middle Atlantic and New England during the 1980s. It is now located from New Hampshire to North Carolina. HWA has destroyed thousands of acres of hemlock forest in New Jersey, Maryland, New York, Connecticut, and Pennsylvania and is spreading at a rate of 10 to 15 miles per year (McClure 2001).

Arborists have eradicated HWA populations on individual trees through semi-annual drenching with horticultural oils and insecticidal soaps. They also have reported that trunk and soil injections of imidacloprid are effective at eliminating HWA populations on individual trees, and chemical residues within the tree may prevent re-infestation for up to 2 years. There is no substance that can be aerially applied over large acreages of forest.

The predatory beetle *Pseudoscymnus tsugae* has been released by federal and state agencies as a biological control for HWA in very limited areas of highly infested forest since 1998. Research on this insect indicates that it may become an effective biological control agent within 6 to 10 years (Onken personal communication, 2001).

Because there is not an effective treatment that can be applied over large areas in a relatively short period of time, there has not been research or application of multidimensional management techniques reported for hemlock forests infested with HWA. We have begun development and implementation of management strategies for large landowners in Northeastern Pennsylvania and Southern New York. This report details our approach and some preliminary findings.

Methods

In Northeastern Pennsylvania and Southern New York, hemlocks typically occur in mixed-species stands. Pure stands are usually less than 10 acres in size. Stands, which have the greatest impact on local biodiversity, are frequently located along stream corridors or near wetlands. Clients who request management typically have forests that range from 1 acre to 100 acres. For these clients we employ a four-step management strategy:

1. Evaluation. A determination of the health of the forest and individual specimens. There are three components to this evaluation:

    A. General overview of specimen and forest health. This requires evaluation of needle drop, leaf color, individual tree form, stand age and the age of significant individuals, damage to trunk and roots, etc.

    B. Level of infestation. This requires an analysis of HWA populations within the forest and on individual trees. Counts of HWA on branch-tips may need to be taken at random points throughout the forest to determine the length of time the infestation has been present and whether HWA populations are increasing or decreasing. It is also necessary to remove random branch tips and determine if elongate hemlock scale (*Fiorinia externa*) or circular hemlock scale (*Nuculaspis tsugami*) is present. In the northeast, these insects can be primary and secondary agents of hemlock mortality, and they do not respond well to HWA management strategies.

    C. Landowner intensity. It is necessary to determine the emotional, technical, and financial level of commitment for each forest landowner. As described below, the management plan must be customized to fit client expectations.

2. Management. There are four management options currently available to forest landowners. These may be applied individually or in combination depending on the results of the evaluation.

    A. The only systemic insecticide used extensively to control HWA is Imidacloprid, produced by the Bayer Corporation. Imidacloprid comes in a dry form (Merit®) that is mixed with water for soil injection and a premixed liquid form (Pointer®) for trunk injection. Imidacloprid is a systemic chloronicotinyl insecticide utilized for control of a wide variety of aphid, lacewing, and other garden pests (Mullins and

Christie 1995). In garden applications, non-certified individuals can apply Merit® as a foliar spray in low concentrations. Applied in trunk or soil injections, high concentration doses of Merit® or Pointer® must be applied by a certified pesticide applicator. Soil injections are applied by a Kioritz® soil injector. (Kioritz® Corporation, 7-2, Suehirocho 1-chrome, Ohme, Tokyo 198-0025, Japan). This injector is a hand-held device that delivers pre-measured and pre-mixed doses of liquid into the soil at a depth selected by the applicator between 7.6 and 20 cm. Trunk injections can be applied using the Mauget® system or by a Wedgle® applicator (Arbor System Injection System, Pat. No. 5.239,773). The Mauget® system is a pressurized, slow-release system that drills small holes into root-flare of individual trees. Installing a Mauget takes up to one hour and a specially trained applicator must return to the tree to retrieve small capsules, which are left in place for several days until the chemical is absorbed into the vascular tissue of the trees. This system is popular in ornamental applications but time consuming and impractical in forests. The wedgle is a small mobile hand-held device. The imidacloprid is delivered into the cambium through a small needle attached to a mechanical lever that dispenses a premeasured and premixed dose. The wedgle is capable of injecting hundreds of trees each day and does not require a post-treatment visit.

Imidacloprid is reported by the manufacturer to be relatively immobile in soil and to have a very low phytotoxic effect on trees and shrubs. Bayer reports that the product is highly toxic to aquatic invertebrates and should not be applied directly to water or in areas where surface water is present. The product also is reported to demonstrate properties and characteristics associated with chemicals detected in groundwater and the use of the chemical is discouraged in areas with shallow groundwater.

a. Soil injection. EcoScientific Solutions (ES) utilizes a Kioritz® soil injector to apply Merit® (active ingredient imidacloprid) to trees with moderate or severe HWA populations. The chemical is dispersed into the soil and taken up via tree roots into the vascular tissue of the each tree. Applications should only be made during the growing season to encourage uptake by root tissue. We apply dosage according to the manufacturer suggestion: "1.6 oz (1 packet) per 24 to 48 inches of cumulative trunk diameter." (Bayer Corporation, EPA Reg. No. 3125-439). Soil injection is the preferred option when the evaluation determines the following:
    - Trees are less than 8 inches dbh.
    - There is a stem density of hemlocks more than 100 trees/acre.
    - There are no wells, streams, or wetlands within 50 feet of the treatment area.

b. Trunk injection. ES utilizes a Wedgle trunk injector to apply Pointer® (active ingredient imidacloprid) to trees where moderate or severe HWA populations are present. The chemical is dispersed directly into the cambium

of each individual tree. We inject "1 ml per 4 to 6" of trunk circumference" (Arbor System, LLC EPA Reg. No. 69117-1. EPA Est 4346-NB-1), at 4.5 feet above the ground. Modifications to the injection pattern may be made at the applicator's discretion and injections along the root flare may occur if chemical uptake is not occurring at 4.5 feet. Trunk injection can only occur when the pressure within the cambium is neutral or negative. Our personal experience indicates that this condition exists from mid-spring until early summer and again from late summer until the first hard frost. Trunk injection is the preferred option when the evaluation determines the following:

- Trees are greater than 8 inches dbh.
- Trees are scattered throughout the forest.
- There are wells, streams, or wetlands within 50 feet of the treatment area.
- Landowner preference is to avoid chemical application to soil.

B. Harvest or salvage. We recommend the harvest or salvage of hemlocks under the following conditions:

- Needle drop is greater than 75% on most trees.
- Trees with needle drop of 50% or more are in a hazardous position.
- Standing dead trees and accumulated debris are a potential fire hazard.

C. No action. We recommend no action under the following conditions:

- Trees are in relatively healthy condition.
- Less than 20% of branch tips are infested with HWA.
- There is no significant secondary pest infestation.

D. Release of Biological Control. We recommend that landowners attempt to secure the release of *Pseudoscymnus tsugae* under all of the following conditions.

- Forest size is greater than 100 acres.
- Hemlock health is good.
- Infestation is less than 5 years old.
- Infestation rates are at least 75% on new growth of major specimens.

3. Restoration. The ultimate goal for most forest landowners is the restoration and conservation of their hemlock forest. Infestations of HWA have significant impacts on specimen tree and forest health. Therefore, we also have implemented several management strategies to restore vigor and vitality.

A. Irrigation. "Because hemlock is a shallow rooted tree, it is particularly prone to stress when precipitation is abnormally low" (McClure 2001). Individual trees in residential or institutional settings, located on well-drained soils should be irrigated when precipitation rates fall below 1.0 inches/week during the growing season (McClure 2001).

B. Root stimulating fertilizers. The addition of B vitamin fertilizers can have a positive effect in nutrient uptake on trees damaged by disease or insect infestation.

Therefore, we recommend application of these fertilizers to enhance recovery of individual specimens in residential and institutional locations.

C. Nitrogen fertilizer. Long-term HWA infestation reduces foliage density and the ability of the tree to photosynthesize. Therefore, we recommend standard applications of nitrogen fertilizers to encourage new tip growth. It is important to note that HWA generally prefers to infest the newest tip growth; therefore using nitrogen fertilizers on infested hemlocks may greatly increase HWA populations. Nitrogen fertilizers are recommended *after* the adelgid population has been effectively removed from the tree.

D. Regeneration. Regeneration in stands where HWA has caused mortality can be encouraged. We recommend monitoring and removing invasive species, as well as establishing fencing where predation from deer is possible.

E. Land Use. Human impact can cause unnecessary stress to the trees. Trails and parking areas often damage the trees' root systems. We advise relocating or redesigning both trails and parking areas which pose a threat.

4. Monitoring. Following development and implementation of the steps above, it is necessary to educate the forest landowner about watching for signs of a returning HWA infestation. We instruct landowners to conduct random surveys of branch tips on trees throughout their property. We specifically recommend that they watch for the re-appearance of characteristic HWA white woolly covering from Thanksgiving through Independence Day.

Results

We have evaluated approximately 35,000 acres of forest for 35 clients. We have trunk injected approximately 4,300 trees and soil injected approximately 1,000 trees. We are currently monitoring approximately 1,100 acres of hemlock to determine the long term effectiveness of our management techniques.

The specific sampling intensity, technical accuracy, and precision of our evaluations and monitoring depends on the desires and financial resources of the clients. In most cases, clients are satisfied with professional judgment to direct applied management options.

Our anecdotal observation and testimonials from clients indicate that HWA populations will be reduced or eliminated within 3 months after imidacloprid treatment (Salom personal communication, 2001). To begin quantifying these observations, ES injected 75 heavily infested trees at Bushkill in October of 2000. Preliminary assessment of 15 of these trees in the spring of 2001 found live adelgid on 11 of 348 tips analyzed. Dead second stage nymphs were abundant on all branches as observed in videos shown to the trustees this spring. HWA populations were high in visual observations of non-treated trees.

ES conducted a second assessment of trees treated in October of 2000 in the fall of 2001. Seven treated trees and two un-treated trees were examined (Table 1).

This assessment shows that live adelgid could be found on 6.5% of 2001 growth, 1.2% of 2000 growth, and 0.31% of 1999 growth. No more than three individual adelgids could be found on an individual branch tip. Untreated branch tips had an infestation rate of 86% for 2001 growth, 40% for 2000 growth, and 50% for 1999. Adelgid densities for 2001 averaged almost 10 adelgids/ branch tip.

Table 1. Imidaclopred Treatment Results.

		Growth Year 2001			Growth Year 2000			Growth Year 1999		
	Tree #	# of Branch Tips	Branch Tips Infested	Total Individual HWA	# of Branch Tips	Branch Tips Infested	Total Individual HWA	# of Branch Tips	Branch Tips Infested	Total Individual HWA
Treated	122	17	2	3	63	1	1	35	0	0
	63	1	0	0	41	0	0	30	0	0
	71	14	1	2	75	1	1	47	0	0
	28	0	0	0	67	1	3	55	0	0
	30	39	3	7	121	3	6	72	1	1
	27	21	0	0	44	0	0	29	0	0
	72	0	0	0	90	0	0	57	0	0
	Total	92	6	12	501	6	11	325	1	1
Untreated	1	3	3	38	26	16	42	10	8	14
	2	32	27	301	20	12	35	10	2	3
	Total	35	30	339	46	28	77	20	10	17

Discussion

There is growing interest in HWA management by forest landowners. The strategy that we have developed is largely based on personal experience, professional judgment, anecdotal observation, and testimonials from other arborists and foresters. We have found that many landowners have strong emotional attachment to hemlock trees and hemlock forests. They will attempt short-term chemical eradication of HWA on a large scale in the hope that long-term biological control of HWA becomes effective.

There is limited information on the effectiveness of imidacloprid on hemlock pests, especially in forests. The first documented study found 95% mortality of HWA in October after 0.25 oz. in 1-gal. of water/in. dbh was injected 6 to 9 inches into the soil in May (Steward and Honer 1994). Only one study has been published specifically on the topic of imidacloprid uptake in hemlocks. Tatter et al. (1998) examined the uptake of two ornamental eastern hemlock trees in Massachusetts. One was soil injected and one was trunk injected. They report that it took 4 weeks for trunk injections and 6 weeks for soil injections to reach lethal dose concentrations for most “sucking tree

pests." Lethal doses were maintained over 28 weeks. Imidacloprid is believed to be transported through the xylem (Steward et al. 1995; Tattar et al. 1998) and HWA feeds in xylem ray parenchyma cells in the twig (Young et al. 1995).
However, forest management for HWA in a scientific and professional manner requires collection of more basic scientific data. Managers must have data on the movement rates and concentrations of imidacloprid in large forest trees, the residual time of imidacloprid in these trees, and the reinfestation rates of forests after treatment.

We anticipate that *Pseudoscymnus tsugae* and other control agents may become available for private purchase by 2004. It is necessary to determine the long-term effectiveness of this beetle in controlling HWA so that private landowners can make informed decisions. Further, it is would be extremely useful to understand the relationship, if any, between *P. tsugae* and imidacloprid. We believe that a combination of chemical injection and biological control may eventually provide a localized and long-term "cure" for HWA.

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