# Efficacy and Residual Activity of Two Systemic Insecticides for Control of Hemlock Woolly Adelgid on Young Eastern Hemlocks

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## Abstract

The hemlock woolly adelgid, *Adelges tsugae* Annand, is an exotic pest of eastern, *Tsuga canadensis* (L.) Carr., and Carolina, *T. caroliniana* Engelm., hemlock in the eastern United States. *Adelges tsugae*, alone or in combination with other stressors such as the hemlock borer, *Melanophila fulvoguttata* (Harris), drought, and windthrow, are adversely affecting the distribution and abundance of this ecologically and aesthetically valuable tree. Until widespread and effective biological control programs become operational, chemical control is the only tool available to pest managers to save trees doomed by *A. tsugae* infestations. We report results of a systemic insecticide trial initiated in 2000 to compare the dose rate, efficacy, and residual activity of thiamethoxam, currently unregistered for operational use against *A. tsugae*, with that of the commercially available systemic insecticide, Merit®.

Results indicate the lowest dosage of thiamethoxam (0.74 g active ingredient/2.5 cm tree diameter), applied in the spring, works as well at the middle and high rates. Thiamethoxam affects *A. tsugae* populations faster than Merit®. Although remnant HWA populations remain on treated trees, the distal 30 cm of sample branches remains uninfested 19 months after injections. Suggestions for further study and implications of these results for pest managers is discussed.

## Keywords:

Hemlock woolly adelgid, chemical control, thiamethoxam, imidacloprid.

## Introduction

Exotic forest pests have been responsible for the decline of several commercially important tree species in North America (Shigo 1972; Houston and O'Brien 1983; Freisen 1995; Iskra and Haugen 1999). For example, chestnut blight, *Endothia parasitica* (Murrill) Anderson, has nearly eradicated the American chestnut, *Castanea dentata* (Marsh.) Borkh. (Wiggington 1980; Smith 2000). The hemlock woolly adelgid, *Adelges tsugae*, is another example of an exotic forest insect pest that threatens the abundance and distribution of its primary hosts, eastern and Carolina hemlock. Although present in the eastern United States for more than 50 years, only during the last 15 years has *A. tsugae*, in combination with other stressors such as drought and secondary insects

like the hemlock borer, seriously affected the health of hemlock-dominated ecosystems (Evans et al. 1996; Souto et al. 1996).

There is an urgent need to protect mature eastern hemlock shade trees from this destructive exotic forest pest. Research is currently being done on the feasibility of biological agents of *A. tsugae* in the eastern United States (Salom et al. 2001). More work is needed before full-scale implementation of biological control can be achieved. Foliar and soil injected insecticide treatments have been evaluated for *A. tsugae* control and results are very positive (Steward and Horner 1994; Rhea 1996; Steward et al. 1998). One commercially available systemic insecticide for control of *A. tsugae* is Merit® (Bayer Corp., Kansas City, Missouri), which contains the active ingredient imidacloprid, a chloronicotinyl (1-[(6-chloro-3-pyridinyl) methyl]-N-nitro-2-imidazolidinimine) insecticide. Imidacloprid has been shown to significantly reduce *A. tsugae* populations (Steward and Horner 1994; Rhea 1996) as well as other ornamental pests (Steward et al. 1998). We were interested in evaluating a new systemic insecticide, thiamethoxam (Syngenta Corp., Greensboro, North Carolina), for use against *A. tsugae*. Thiamethoxam is a thianicotinyl (4H-1,3,5-Oxadiazin-4-imine, 3-[(2-chloro-5-thiazolyl) methyl] tetrahydro-5-methyl-N-nitro) insecticide, not currently registered for use against *A. tsugae*.

We initiated an experiment to determine the efficacy of thiamethoxam at reducing *A. tsugae* populations; determine the most effective dose rate of thiamethoxam for control of *A. tsugae*; and determine the residual activity of thiamethoxam in treated trees. For the first and third objectives, we also compare efficacy and residual activity of Merit® with that of thiamethoxam.

## Methods

Twenty-five of the most heavily-infested hemlocks were selected from a plot of trees located at the Price's Fork Research Station of Virginia Tech. Trees were ca. 7 years old, ranged from 1.1 to 2.2 m in height, and were either open-grown or had slight overlap of the live crown up to a height of 1.5 m. The diameter of the trees ranged from 2.3 to 5.3 cm at a height of 30 cm on the trunk. Fraser fir, *Abies fraseri* (Pursh) Poir. and white pine, *Pinus strobus* L., of similar age as the hemlocks, make up ca. 35% of the trees in the plantation. Tree spacing was 1.5 m within and between rows. The entire stand was mowed weekly to minimize competition between hemlocks and weeds, and to facilitate assessments.

Each tree was assigned one of five treatments randomly for a total of five trees per treatment. Treatment 1 (control) was soil drench of 19 liters of water. Treatment 2 was a soil injection of Merit® at 0.56 g imidacloprid/2.5 cm of tree diameter and a soil drench of 19 liters of water. Treatments 3, 4, and 5 were soil injections of thiamethoxam at 0.74, 1.12, and 1.49 g ai/2.5 cm of tree diameter and a soil drench of 19 liters of water, respectively. Prior to treatment during early March 2000, a mid-crown branch from each cardinal direction was selected on each sample tree (4 branches x 25 trees = 100 branches total) and branches were inspected visually to determine pre-existing *A. tsugae* infestation levels. The *A. tsugae* infestation level was determined by calculating the percentage of the number of shoots infested by *A. tsugae* (i.e., at least one *A. tsugae* woolly mass per shoot) compared to the total number of shoots found on the distal 30 cm portion of each

branch. Trees were treated during mid-March 2000 using a Kioritz injector (Kioritz Japan Corp., Tokyo, Japan). Insecticides were delivered 15 cm below the soil surface at the base of each sample tree, with the volume given each tree applied equally to each cardinal direction. Following treatment, the same branches assessed in early March 2000 were inspected in June and October of 2000 and March, June, and October of 2001.

The crown of one control tree was overlapped to the north, northwest, northeast, and to the south by the crowns of treated trees. Consequently, this tree was omitted from the analysis because it was suspected that its root system absorbed some insecticides, which would have affected the abundance of *A. tsugae* in the crown.

A one-way analysis of variance (ANOVA) (PROC GLM) (SAS 1996) was used to determine if a significant proportion of the variation in pre-existing *A. tsugae* infestation levels was attributable to the trees chosen for each treatment and if a significant proportion of the variation in *A. tsugae* infestation levels was attributable to the dose rate of thiamethoxam applied. A three-way ANOVA was used to determine whether a significant proportion of the variation in *A. tsugae* infestation level was attributable to treatment, date, and cardinal direction. Infestation level data was arcsine square root transformed prior to all analyses. Results appear as means ± SE and differences were considered significant at the 5% probability level.

## Results

A significant proportion of the variation in *A. tsugae* infestation levels was not explained by the trees chosen for treatment ($F_{4,95}$ = 1.91, $P$ = 0.11) (Figure 1). Thiamethoxam application rate did not explain a significant proportion of the variation in *A. tsugae* infestation levels ($F_{2,359}$ = 2.62, $P$ = 0.21). Consequently, data for this treatment were pooled in the next analysis. Infestation levels of

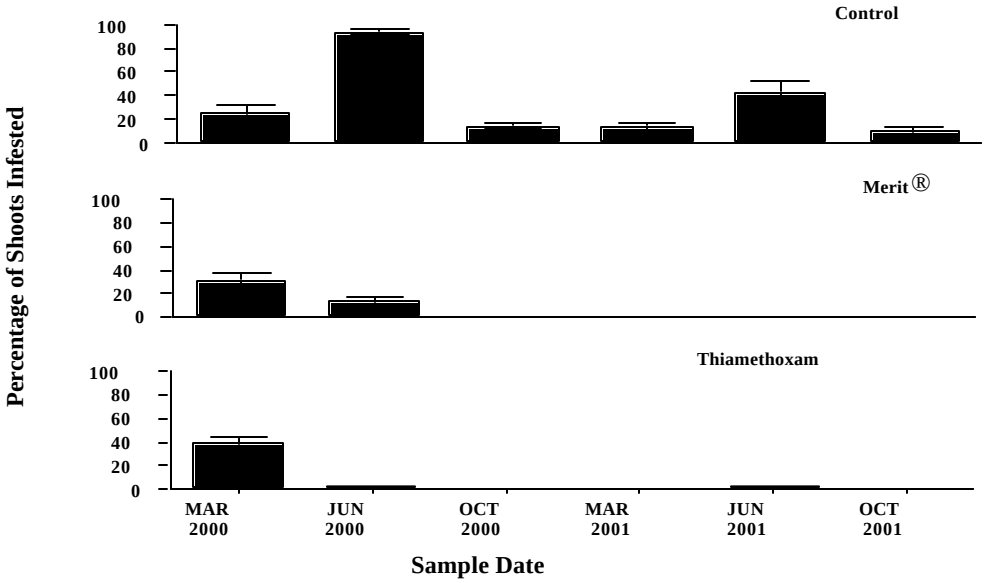


**Figure 1.** Influence of treatment and sample date on population levels of *A. tsugae* infesting young eastern hemlock. A significant proportion of the variation in *A. tsugae* infestations levels was explained by the treatment *x* date interaction ($F_{10,575}$ = 31.14, $P$ = 0.0001).

*A. tsugae* decreased faster on thiamethoxam-treated trees than on Merit-treated trees but did not decrease significantly on the control trees (Figure 1), resulting in a treatment *x* date interaction ($F_{10,575}$ = 31.14, $P$ = 0.0001). As of October 2001, *A. tsugae* has still not recolonized the distal 30 cm portion of the sample branches of treated trees (Figure 1).

## Discussion

*Adelges tsugae* populations were eradicated from the distal 30 cm of the sample branches of trees, regardless of the dosage of thiamethoxam applied during the spring. Therefore, the lowest concentration of thiamethoxam used in this study (0.74 g ai/2.5 cm of tree diameter) is recommended in further studies. Steward et al. (1998) obtained good control of *A. tsugae* populations with a fall injection of Merit®. A similar assay should be conducted with thiamethoxam.

When comparing the efficacy and residual activity of thiamethoxam with that of Merit®, there were three main observations that emerged from this study. First, thiamethoxam worked faster than Merit®. Rhea (1996) and Tattar et al. (1998) observed that Merit ® may take from one to three months to reach lethal concentrations in the foliage of hemlock Thus, thiamethoxam may prove beneficial in situations where the manager feels he/she cannot wait at least a month or more for Merit® to become effective.

Second, the sample branches of trees treated with both systemic insecticides still have very low *A. tsugae* infestation levels 19 months after treatments were applied and, therefore, both insecticides have similar residual activity. All trees will be checked again during March 2002, which is 24 months post-treatment. Rhea (1996) observed that foliar applications of imidacloprid had a residual effect of at least one year following treatment. These findings suggests that yearly applications may not be necessary, although yearly checks are very important.

Third, Merit® was as efficacious as thiamethoxam at a lower dosage rate (0.56 g ai/2.5 cm tree diameter and0.74 g ai/2.5 cm tree diameter, respectively). The per gram cost of Merit® and thiamethoxam is ca. $0.64. Therefore, Merit is cheaper than thiamethoxam and gives the same level of control and residual activity. We recommend thiamethoxam be evaluated, at least, at 0.56 g ai/2.5 cm tree diameter.

We have observed remnant *A. tsugae* populations on the least vigorous shoots of many treated trees, suggesting either the dosage of insecticides was not sufficiently high to eradicate all *A. tsugae*, or *A. tsugae* feeding on parenchyma cells of shoots of low vigor (i.e., lower and/or inner crown shoots) do not acquire a lethal dose, or both. Estimates of *A. tsugae* populations on the sample branches were, therefore, only a relative estimate between trees given different treatments. Until a suitable sample unit is developed for this pest, we recommend that whole mid-crown branches instead of parts of branches be assessed in further studies.

These findings suggest that thiamethoxam could be another useful control tool if registered for use against *A. tsugae*, that is, until some widespread and effective biological control programs become operational.

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