Eastern hemlock (Tsuga canadensis Carrière) covers a wide range of the United States, from New England, New York, Pennsylvania, and the Mid-Atlantic states, expanding westward from central New Jersey to the Appalachian Mountains, and continuing south into northern Georgia and Alabama. In the Midwest, hemlock occurs predominantly in eastern Ohio, northern Michigan, and Wisconsin (USFS). First identified in the early 1950s in Virginia, U.S., hemlock woolly adelgid (Adelges tsugae Annand) (Hemiptera: Adelgidae) (HWA) is an invasive insect that infests hemlock trees. It is considered a pest of Tsuga canadensis Carrière and T. caroliniana Engelmann. The biotype of HWA found in eastern North America genetically matches populations native to the island of Honshu, Japan (Havill et al. 2006). HWA occurs in India, Japan, and China, on four Asiatic species, including T. dumosa Eicher, T. forrestii Downii, and T. chinensis Pritz (Montgomery et al. 2000). Symptoms of HWA infestation include canopy thinning, twig dieback, tree decline, and ultimately death. HWA has spread and now infests approximately half of the eastern native range of hemlock.

Low temperatures may play a role in HWA mortality, thereby limiting its northward spread. Although the cold temperature sensitivity of HWA varies seasonally, substantial mortality occurs at temperatures of -30°C to -25°C (Costa et al. 2004). Such low temperature extremes may occur infrequently, or not at all, in the southern extent of the hemlock range. At least one study suggests that hemlock decline is more rapid in southern Appalachia compared to northern areas (Nuckolls et al. 2009).

HWA has piercing–sucking mouthparts and feeds within the xylem parenchyma cells (McClure 1987) on twigs at the needle base. The xylem parenchyma is living symplast that is rich in carbohydrates and other essential nutrients; as adelgids feed on these food resources, less is available for foliar growth and other essential functions (Shigo 1989). As an infestation progresses, twig lengths decrease, followed by loss of tip growth. McClure (1991) suggested an inverse relationship between HWA population and hemlock growth. This growth loss occurs with increasing HWA pressure and may take three to four years; the impact may be compounded by drought or poor tree vigor. Ward (1991) suggested a threshold of 25–30 HWA/100 needles as negatively impacting twig growth. Doccola et al. (2007) suggest a threshold of 2–4 HWA/cm twig growth.

McClure (1992) investigated the efficacy of organophosphate insectide injections and implants for the control of HWA. He reported significant HWA mortality four weeks and five months after treatment. The efficacy of soil injected imidacloprid against HWA has been reported (Steward and Horner 1994; Steward et al. 1998). The translocation of imidacloprid applied to the soil and by trunk injection have been the subject of some investigation (Tattar et al. 1998; Dilling et al. 2010). Tattar et al. (1998) studied three species (Quercus palustris, Tsuga canadensis, and Pinus strobus), one of each pair receiving soil-applied imidacloprid, the other receiving trunk-injected imidacloprid. Imidacloprid reached lethal concentrations (established at 0.15 ppm, the LC95 for Myzus persicae, the peach tree aphid) in one week in Q. palustris tree injection compared to eight weeks for soil application, whereas in
T. canadensis, the LC₉₅ occurred in four weeks and 12 weeks, respectively. Interestingly in P. strobos, soil applications reached lethal concentrations in 12 weeks, but tree injected imidacloprid did not reach the LC₉₅ for five months. Dilling reported imidacloprid peaking in T. canadensis 9–12 months following soil applications or tree injections, although none achieved residues of 0.300 μg/g, the LC₉₅ for HWA (Cowles et al. 2006). Trunk injected imidacloprid translocated relatively quickly into the foliage of Ulmus spp. and reduced defoliation by elm leaf beetle, Xanthogaleruca luteola (ELB) (Lawson and Dahlten 2003). The authors suggested that tree injection treatments after sampling egg density offered an advantage over soil-applied treatments that required application in the winter months (presumably when moisture is more available in the area of Sacramento, California, U.S.) for absorption and translocation. Bioassays showed imidacloprid toxicity to ELB larvae at 33 days but not at one year after treatment. Poland et al. (2006) reported rapid translocation of imidacloprid in three host species (Populus nigra, Salix matsudana, and Ulmus pumila) to Asian longhorned beetle, Anoplophora glabripennis, with significant mortality up to nine months after treatment. Leaf and twig residues of imidacloprid ranged from 0.27 to 0.46 ppm. Studies in green ash (Fraxinus pennsylvanica Marsh) and white ash (F. americana L.) have reported that imidacloprid accumulates in the canopy from the point of injection and is lost in leaf fall, but suggest that stem injection could provide a reservoir for continued systemic activity (Cregg et al. 2005; Tanis et al. 2006; Tanis et al. 2007; Tanis et al. 2009). Imidacloprid residual activity in hemlock has been investigated and reported (Cowles et al. 2006; Doccola et al. 2007). Cowles et al. (2006) reports that a single soil application of imidacloprid suppresses HWA for >2 years. Doccola et al. (2007) reported HWA control following imidacloprid tree injection for two years; however, residues were not conducted in that study. The differences in the time injected hardwoods and conifers accumulate imidacloprid (e.g., Tattar et al. 1998) is consistent with Hagen-Poiseville law which describes the rate of flow as a function of the xylem radius to the fourth power (Kramer et al. 1996). Therefore, hardwoods that have wide vessels (e.g., oaks) move liquid at a faster rate than conifers, which move liquids solely by comparatively narrow tracheids (e.g., hemlocks, pines) (Esau 1977). Even so, there must be an alternative explanation for the slow movement of imidacloprid observed in conifers. The physical chemistry of imidacloprid (e.g., water solubility, affinity to organic carbon) may play a role in its differential movement upward in trees. However, such an investigation is beyond the scope of this paper.

This study focused on imidacloprid treatment efficacy in the southern part of the hemlock range, where HWA has been devastating. Imidacloprid, a neonicotinoid insecticide, is labeled for use and studies have established its efficacy in managing HWA (Steward and Horner 1994; Steward et al. 1998; Webb et al. 2003; Cowles et al. 2006; Doccola et al. 2007). Imidacloprid is available in water soluble packets (WSP), in soluble tablets, or in liquid (SL) formulations, and may be applied to the foliage, soil, or injected directly into the tree. The latter two methods rely on systemic movement of insecticide from the point of application upward into the canopy. Soil and tree-injected formulations are efficiently applied to trees in forested and woodland settings. While spray applications are more commonly used, there may be advantages to combining soil and tree injections for short-term therapeutic and sustained tree protection in some instances.

The feeding habits of adelgids favor systemic applications. For systemic activity, the insecticide must move upward in the vascular tissues, to concentrate at the growing points at which insects feed. Soil-applied imidacloprid needs to be in solution to be absorbed by tree roots before systemic activity can occur. Trunk-injected imidacloprid is directly introduced into the sapwood for movement upward into the canopy. Methods of soil application include basal drenches, soil injection, or the use of soluble tablets. The availability of soil-applied imidacloprid (to the tree) depends upon soil moisture, which may be inconsistent in woodland environments. A possible disadvantage to these techniques is their slow action. Imidacloprid applied to soil binds to fine soil particles and to organic matter (organic carbon coefficient, ~350) and is slowly dissolved by moisture in the soil (water solubility of imidacloprid is 0.51 g/Liter) (Cox et al. 1977; EXTOXNET-PIP/Imidacloprid). Soil-applied treatments maintain residual activity over several years (Cowles et al. 2006) and are simple and quick to apply.

Eastern hemlock trees in this study were in poor condition and declining; the trees had thin, sparse foliage and twig dieback. Tree recovery depended on the immediate and sustained adelgid control. Webb et al. (2003) reported that recovery and dramatic new growth of hemlock in poor condition occurred following imidacloprid treatment, although at a slow rate.

Woodland trees depend upon natural rain events for moisture, which could be highly variable. Cruziat et al. (2002) discuss the increase in hydraulic resistance at the soil–root interface during periods of drought and among its consequences: reduced water absorption, conductance, and stomatal closure. Drought was of particular concern because shoot growth, which is critical to tree recovery, depends on adequate soil moisture (Onken 1994), and root uptake of soil-applied imidacloprid depends on it being dissolved (i.e., available) in the soil solution.

The study objectives were to evaluate tree responses to different methods and rates of imidacloprid application and to evaluate the extent of residual activity of the treatments. To evaluate the effectiveness of the techniques, assessments were conducted on HWA density and twig growth, and imidacloprid was extracted from hemlock needles for three years.

MATERIALS AND METHODS

Study Site
Eastern hemlock (Tsuga canadensis) trees were selected for treatment: large diameter, mature trees ~30 meters in height located on the Biltmore Estate in Asheville, North Carolina, U.S. (latitude: 35.567°N, longitude: -82.5448°W). Treatments were assigned at random in two blocks. In poor condition and declining, the trees had thin, sparse foliage with tips dying back. The trees had ~25% live crown ratio, and ranged from 26.5 to 86.8 cm diameter at breast height (DBH) with a mean DBH of 49 cm.

Application Techniques
Forty-eight hemlocks were treated with insecticide formulations containing the active ingredient imidacloprid (1-(6-chloro-3-pyridinyl) methyl]-N-nitro-2-imidazolidinimine) for HWA.
infestations. Six treatments were assigned in two randomized blocks, each of which was replicated eight times. The treatments were (1) untreated controls (UTC), (2) IMA-jet [5% (g/g) imidacloprid SL systemic insecticide; Arborjet, Inc., Woburn, Massachusetts, U.S.] low rate, (3) IMA-jet high rate, (4) IMA-jet low + Merit® 75 WSP [75% (g/g) imidacloprid; Bayer Environmental Science, Research Triangle Park, North Carolina, U.S.] soil injection, (5) IMA-jet high + Merit soil injection, and (6) Merit soil injection alone. Soil injections were made using the Kiortiz® (Kiortiz Corporation, 7-2, Suehirocho 1-Chome, Ohme, Tokyo, 198 Japan) injector; applications were made 30–90 cm away from the tree bole, where the fibrous roots were most likely concentrated. Each Merit 75 WSP 45.4 g packet was mixed in 960 ml of water, per label instructions. The Arborjet® Tree I.V. and the QUIK-jet® injector were used to make the tree injections. Low rates of imidacloprid were applied at 0.15 g a.i./2.5 cm DBH, high rates were applied at 0.30 g a.i./2.5 cm DBH, and soil injections were made at 1.45 g a.i./2.5 cm DBH. QUIK-jet injections applied 3 ml IMA-jet per 2.5 cm DBH and the TREE I.V. applied 6 ml IMA-jet per 2.5 cm DBH. For example, in a 50 cm DBH tree, 60 and 120 ml of IMA-jet were applied for low and high dose injections, respectively. The IMA-jet formulation was applied at rates lower than the 4 to 8 ml (0.2 to 0.4 g) a.i./2.5 cm DBH label use recommendations. Tree injections of imidacloprid were applied as formulated. The injection site was made into the trunk flare (i.e., basally) using a 9 mm Brad point bit, drilled 3.75 cm into the sapwood and fitted with an Arborplug® (a backflow prevention device) to create a 2.5 cm³ capacity site to mitigate for slow uptake in the sapwood tracheids. The number of application sites varied from 15 to 20 cm of stem circumference for the QUIK-jet and Tree I.V., respectively. Treatments were applied on August 29–30, 2007 at the Biltmore Estate. The imidacloprid treatments were timed to coordinate with the re-sumption of adelgid activity following summer aestivation. The amount of time for each treatment to be applied was recorded.

### Tree Assessments

Branch samples were taken from trees each November from 2007 to 2010 (at approximately 70, 435, 800, and 1,165 days after treatment) for assessment and imidacloprid residues (Table 1). Autumn was selected for sampling because tree growth was expected to be complete, HWA resumed development following summer aestivation (therefore were easier to assay), and before low temperature events could adversely affect HWA survival. Four branches were cut, each between 40 and 60 cm in length, from the mid-tree canopy in four sectors by aerial lift truck, and shipped to Arborjet, Inc. for evaluation. Branches were refrigerated at 4.4°C until the assessments were conducted. Digital scans were made of all of the branch samples, using a Canon Color Image Scanner (Canoscan 8800F); the digital images captured the temporal changes in tree condition. Percent tip growth was estimated for each branch sampled, and the mean calculated for each tree. Tip growth was determined on a percentage basis, adapting the method by Webb et al. (2003). Within a treatment, percentage of branches with new tip growth was determined by dividing the number of tips with new growth by the total tips counted, multiplied by 100. Each branch was then cut into five shorter branchlets (terminal, plus four laterals) to evaluate the number of HWA per cm of new growth. HWA infestations were assessed by microscopic examination. The number of HWA on twigs with needles was counted, branch length was measured, and the value HWA / cm was calculated.

### Table 1. Treatments, imidacloprid residues in μg/g (ppm), percent tip growth, and HWA infestation per centimeter of branch. The LC₅₀ value for HWA is 0.30 μg/g (Cowles et al. 2006). Per treatment, percent tip growth is a measure of the mean number of tips on branches with new growth.

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>μg/g</th>
<th>% Tip growth</th>
<th>HWA/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>Untreated controls</td>
<td>0.01’</td>
<td>5.60b</td>
<td>0.28b</td>
</tr>
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<td></td>
<td>IMA-jet Lo</td>
<td>0.20a</td>
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<td>0.17b</td>
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<td></td>
<td>IMA-jet Hi</td>
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<td>3.41b</td>
<td>0.00b</td>
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<td></td>
<td>IMA Lo + imidacloprid soil</td>
<td>0.22a</td>
<td>13.04b</td>
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<tr>
<td></td>
<td>IMA Hi + imidacloprid soil</td>
<td>0.86a</td>
<td>7.74b</td>
<td>0.00b</td>
</tr>
<tr>
<td></td>
<td>MERIT soil</td>
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<td>1.62b</td>
<td>0.11b</td>
</tr>
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<td>2008</td>
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<td>2.59b</td>
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</tr>
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<td>2.81b</td>
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<tr>
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<td>72.27a</td>
<td>0.04a</td>
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<td>81.70a</td>
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<td>2010</td>
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<td>60.20b</td>
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</table>

Notes: n = 8. Means followed by the same letter are not significantly different at P < 0.05. Percentage data transformed (asin (sqrt (x/100)))*57.3 prior to ANOVA. Actual means are presented in table.

*Not included in statistical analyses (n < 8).
Imidacloprid Residues

Five additional branchlet samples from each of the four branches were combined, generating ~25 g of hemlock foliage for imidacloprid residues. The foliage was placed into plastic bags, and stored at -18°C until imidacloprid residues were run. Foliage was sent out to independent labs for residue testing. Foliage sent to Bayer Environmental Science determined the 2007–2008 imidacloprid residues; the USDA FS (Pineville, Louisiana, U.S.) conducted the 2009–2010 imidacloprid residues. Samples sent to Bayer were ground in liquid nitrogen and extracted using a modified QuEChERS procedure prior to HPLC-MS/MS analysis (Lehotay et al. 2010). Imidacloprid metabolites that have insecticidal activity include olefinic-, dihydroxy-, and hydroxy-imidacloprid (Sangha and Machemer 1992; Suchail et al. 2001). Imidacloprid, imidacloprid-olefin, and 5-OH imidacloprid residues were reported. Each sample was analyzed in duplicate, and the mean reported. Hemlock foliage sent for the 2009–2010 analyses conducted by the USDA FS were dried, ground in a Wiley mill prior to solvent extraction. For extraction, 1 g of dried hemlock foliage was placed in a 15 ml vial to which 10 ml of methanol was added, and the vial was agitated overnight on a shaker table. The sample was allowed to settle and supernatant drawn for ELISA analyses (Fischer et al. 2009). Polyclonal ELISA (EnviroLogix™; Portland, Maine, U.S.) kit was used in these analyses. Plate absorbance was read using a Biotek ELx808 plate reader (Biotek, Inc., Winooski, Vermont, U.S.) and results calculated using Biotek Gen5 software. Samples outside specified calibration of >6.0 ppb were diluted with deionized water and reanalyzed. Each sample was analyzed in duplicate, and the mean was reported. These (HPLC and ELISA) methods are similar; however the ELISA method is semi-quantitative for imidacloprid and will overestimate imidacloprid because reported residues include imidacloprid plus metabolites (Montfort et al. 1994; Fischer et al. 2009; Frank Byrne pers. comm.). Researchers report the “imidacloprid plus metabolites” of the HPLC and ELISA analyses as imidacloprid residues for the purposes of comparison. Two or three untreated hemlock samples were used for residue analyses and were therefore excluded from statistical analyses. For imidacloprid efficacy, researchers used the published LC50 for HWA of 0.300 µg/g (Cowles et al. 2006) as a reference value. The means are presented in Table 1.

RESULTS

A repeated ANOVA was performed using Proc Mixed (SAS, Inc., Cary, North Carolina, U.S.) on the data across years for each of the three (transformed) responses. The fixed effects in the model were Block, Treatment, Year, and Treatment*Year interaction. Based on preliminary analyses, Block*Treatment was included as an additional fixed effect for LogHWA only. To allow for serial correlations and heterogeneity of variances across years, the error covariance was assumed to be a first-order heterogeneous autoregressive structure using the REPEATED statement with option ARH(1). Comparisons among treatment means averaged over years were performed if the Treatment*Year interaction was not important. If interaction was statistically significant and biologically important, treatment comparisons were carried out separately for each year (in MINITAB Version 15, Minitab, Inc., State College, Pennsylvania, U.S.). Comparisons were carried out using the protected LSD procedure at significance level 0.05. Trend analyses were plotted for each imidacloprid treatment applying a quadratic trend model, which was the best fit for the residue data.

Growth

Digital scans from 2007 to 2010 documented the temporal changes in tree condition (Figures 1). Year effects were highly significant (F = 231.24, DF = 3, 126, P < 0.001) reflecting an increase in growth over time for all treatments. Treatment and Year*Treatment interaction were both significant (F = 10.02, DF = 5, 41, P < 0.001 and F = 3.02, DF = 15, 126, P < 0.001, respectively). A graph of treatment means against year showed that trends were roughly similar across treatments except that the rate of increase was slower for the UTC and soil alone treatments, thus treatments comparisons are based on means across years (Table 1; Figure 2).

Log HWA

Treatment, Year and Treatment*Year interaction were all significant (F = 9.46, DF = 12.49, P < 0.001; F = 12.49, DF = 3,126, P < 0.001; and F = 2.14, DF = 15,126, P = 0.011, respectively). Block and Block*Treatment effects were also significant (F = 16.01, DF = 1, 36, P < 0.001 and F = 5.28, DF = 5, 36, P = 0.001, respectively) mainly because of some high values for soil treatment in Block II. Trends across years are similar for the treatments 2–5 (tree injections +/- soil), but different from UTC and imidacloprid soil treatment, so treatment comparisons are reported separately for each year (Table 1). Means of HWA/cm across years for treatments are presented in Figure 3.

Log Residue

Year effects are highly significant (F = 147.36, DF =3, 105, P < 0.001), Treatment and Treatment*Year interaction are also significant (F = 12.52, DF = 4, 34, P < 0.001 and F = 7.38, DF = 12, 105, P < 0.001, respectively). Trends across years were not consistent across treatments and treatment comparisons are reported separately for each year (Table 1). Means for imidacloprid residues for 70 to 1165 DAT are presented in Figure 4.

Precipitation Data

Onken (1994, unpublished data) reported a direct relationship between the amount of rainfall that trees receive in a given year and the amount of new growth in the following year. Monthly weather summaries were obtained from online data provided by the National Weather Service Forecast Office, Greenville-Spartanburg, South Carolina, U.S. (NOAA), ~80 km from the study site. Monthly total precipitation from 2006 to 2009 was compared to the norm (average).

Statistical Analyses

Data were transformed before carrying out analysis of variance (ANOVA) in order to achieve approximate homogeneity of variances across treatments. The arcsine transformation was applied to the proportion of terminals showing growth. A log transformation was applied to HWA/cm and imidacloprid residues, the specific transformations being Log(HWA/cm + 0.005) and Log(Residue + 0.05), respectively, due to 0 values for each measurement.
Figure 1. Digital scans of hemlock terminals comparing the temporal changes in untreated control to the imidacloprid treatment from 2007 to 2010. From top left, untreated tree showing symptoms of (a, b) thinned foliage, (c) dieback/decline, and (d) branch death. From bottom left, imidacloprid tree and soil injection treatment with (e) thinned foliage and of recovery, (f-h) and progressive twig growth and refoliation.

Figure 2. Mean percentage of growing tips (converted) in hemlock across the years. At the start of the study, <13.0% of trees had new growth, reflecting the poor condition of the trees. Recovery was observed over the course of the study, where injected trees (+/−soil injection) refoliated at faster rates than the soil alone treatment or the untreated trees. Mean refoliation three years after treatment for the injected trees (+/−soil injection), soil injection, and untreated was >84.6%, 60.2%, and 48.5%, respectively.

Figure 3. Mean HWA/cm on new foliage of hemlock across years. At the start of the study, adelgid numbers were low, a result of dieback in trees from the previous years of infestation. As trees put on new foliage, the adelgid populations rebounded and in 2008 approached densities (of 2.0 HWA/cm) that negatively impact hemlock growth. In the subsequent years, HWA collapsed in the imidacloprid treatments, but persisted in the untreated trees.
Above the LC50 HWA of 0.30 μg/g through 2013, 6 years following treatment. This model plots residues for HWA) to four years following treatment, while tree injection + soil injection (Figure 5) and soil injection alone (quadratic equation, Yt = -2.39 + 2.73*t – 0.300*t**2, and Yt = -1.83 + 1.83*t – 0.56*t**2, respectively) forecasts residues >0.300 μg/g to six years following treatment. These results are presented in Table 1 and in Figure 4 in μg of compound per gram of dried needles (i.e., ppm). Trunk injected imidacloprid accumulated more rapidly (1 year) into the canopy compared to soil-applied only imidacloprid. Although soil-applied imidacloprid accumulated more slowly (two years) in the canopy, it may persist longer. Forecast plots were conducted to predict imidacloprid residues beyond three years following treatments. Trend plot analysis for tree injection low dose (quadratic equation, Yt = -2.4 + 3.174*t – 0.56*t**2) forecasted residues >0.300 μg/g (LC50 for HWA) to four years following treatment, while tree injection + soil injection (Figure 5) and soil injection alone (quadratic equation, Yt = -2.39 + 2.73*t – 0.300*t**2, and Yt = -1.83 + 1.83*t – 0.56*t**2, respectively) forecasts residues >0.300 μg/g to six years following treatment.

CONCLUSIONS AND DISCUSSION

The study authors examined HWA-infested trees in the southern part of the hemlock range and collected data on foliage growth, HWA density, and imidacloprid residues for three years. At the time of treatment in 2007, the hemlocks had thinned canopies and significant dieback: 51.6% of the trees were in decline. Only 17.1% of the branch samples collected had enough foliage to conduct an analysis of adelgid activity, from which the adelgid numbers were low. Terminal dieback and low adelgid density indicated a protracted infestation, leaving the stand in poor condition. The trees were treated in late summer to coordinate with the resumption of HWA feeding. Low levels of imidacloprid were recovered from needles of trees treated at 70 days. However, significant growth responses to treatment would not be observed for two years. Translocation upward was likely slowed by sparse canopies and reduced transpiration potential.

As trees refoliated, adelgid density was observed to increase. Three of the treatments (though not statistically significant) had mean adelgid densities that were approximately great enough (~2.0 HWA/cm) to impact hemlock growth, pointing to a need for continued protection. While adelgid density remained high across the years 2008–2010 in the untreated trees, their numbers dropped to negligible levels in the imidacloprid treatments at 800 days and remained so at 1165 days (Figure 3), supporting insecticidal efficacy and residual activity. Imidacloprid residues exceeded the LC50 value for HWA in each analysis conducted after 70 days (Figure 4). The treatments with the highest residues (tree injection +/- soil treatments) at 435 days and 800 days were associated with statistically significant growth in subsequent years (2009 and 2010, respectively). In addition to insecticidal activity, imidacloprid may have played a direct role in aiding refoliation (Chiriboga 2009). Tree responses were positive, but slow, consistent with that reported by Webb et al. (2003), the greatest growth occurred in the second year following treatment (Table 1; Figure 2).

The study authors observed a comparatively slower initial rate of accumulation of residues from the soil alone treatment. Relatively dry soil conditions (in 2007, 2008) may have accounted for the low imidacloprid residues obtained in the first two years studied. Imidacloprid is absorbed by roots when it is dissolved in the soil solution. The sparse trees showed signs of recovery when imidacloprid systemic activity occurred. Though mean residues were ≥LC50 for HWA in 2008, HWA/
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Résumé. En raison de la présence généralisée du puceron lanigère de la pruche (Adelges tsugae Annand) au sein de l’habitat de la pruche du Canada (Tsuga canadensis Carrière), les arbres en milieu forestier peuvent être infestés plusieurs années avant qu’un traitement ne soit effectué. Les symptômes d’une infestation prolongée incluent un dépérissage généralisé et une couronne clairsemée. L’imidacloprid, un insecticide systémique neocotinoïde, s’avère un outil utile et efficace pour contrôler ce puceron. Dans cette étude, des arbres matures de gros calibre et en mauvaise condition ont été traités avec l’imidacloprid. Les arbres ont été traités une fois par injection dans le tronc ou le sol à Asheville en Caroline du Nord aux États-Unis. Suite à cette application, les variations en croissance de l’arbre, la densité en pucerons lanigères de la pruche et la présence résiduelle en imidacloprid ont été mesurées durant trois ans. Les arbres traités avec l’imidacloprid s’en sont sortis tandis que les arbres non traités continuaient d’en souffrir. Les arbres injectés avec l’imidacloprid présentaient une accumulation de ce composé chimique dans leur couronne, ce qui facilitait une reformation des aiguilles et la persistance de l’imidacloprid durant trois ans. Cette activité persistante de l’imidacloprid par injection dans le tronc a été attribuée en partie à son mouvement lent vers le haut au travers du système vasculaire restrictif en trachéides et à la capacité de rétention des aiguilles persistantes. L’imidacloprid par injection dans le sol a été plus lent dans son action systémique, mais il a présenté un plus grand potentiel en terme d’activité à long terme. Les chercheurs ont suggéré qu’une combinaison d’injections dans le sol et le tronc pouvant produire à la fois une action immédiate ainsi qu’une action à plus long terme (quatre ans et plus) constituerait une stratégie efficace et économique pour protéger les arbres de grande valeur.


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