

Using Imidacloprid to Control Hemlock Woolly Adelgid

Charles A. Silcox, Ph.D.

Bayer Corporation
512 Concord Place, Perkasie, PA 18944

Abstract

The chloronicotinyl insecticide imidacloprid has become one of the most widely used insecticides in the world based on its unique mode of action, its excellent activity towards a wide range of pests, and its favorable toxicological and environmental profiles. In the United States, imidacloprid has established an excellent reputation for insect control on turf and ornamentals and this active ingredient is especially effective against the hemlock woolly adelgid (*Adelges tsugae*). Five formulations of imidacloprid are currently available for hemlock woolly adelgid control. Bayer Corporation offers three products (Merit® 75WP, Merit® 75WSP, and Merit® 2F) that may be applied as foliar sprays or soil treatments. Two ready-to-use formulations (Imicide® and Pointer® Insecticide) also are available for use as trunk injections. A particular formulation may be selected based on the desired speed of action and duration of residual control.

Keywords:

Imidacloprid, hemlock woolly adelgid, Merit®, Imicide®, Pointer®.

Introduction

Imidacloprid is a revolutionary insecticide that was first synthesized by Nihon Bayer Agrochem in 1985 (Elbert et al. 1998). Its development followed the discovery of a new insecticide class (the heterocyclic nitromethylenes) by chemists at Shell Chemical (Soloway et al. 1978). These synthetic compounds evolved from the naturally occurring insecticide nicotine (Figure 1) whose mode of action is to interfere with normal nerve impulse transmission by binding to post-synaptic nicotinic acetylcholine receptors. Imidacloprid is the first commercially available compound from a new insecticide class, the chloronicotinyls, which act at this unique site of action.

Imidacloprid possesses a unique combination of characteristics that make it one of the most widely used insecticides worldwide (Elbert et al. 1990; Elbert et al. 1991; Kagabu 1997; Cox et al. 1997; Cox et al. 1998). These characteristics include a novel mode of action that makes imidacloprid an important component of resistance management programs, excellent systemic and contact activity, a wide variety of application methods, low application rates, long residual control, strong binding to soil organic matter, and favorable toxicological and environmental profiles. Merit® insecticide for use on turf and ornamentals became the first full U.S. registration of imidacloprid when it was registered by the Environmental Protection Agency on March 21, 1994.

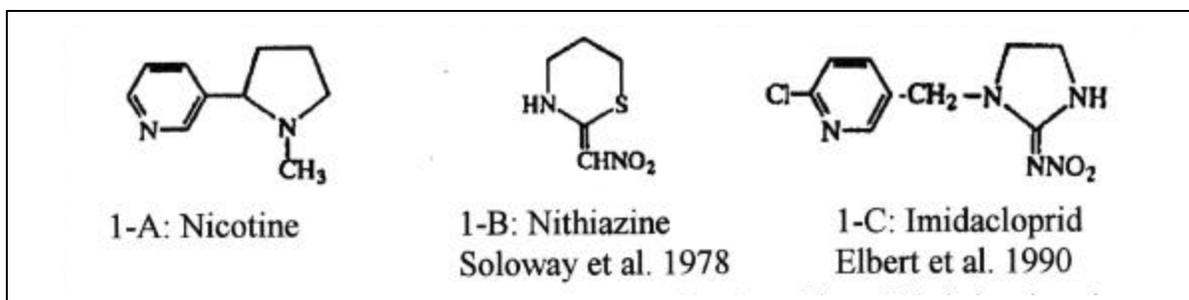


Figure 1. Chloronicotinyl insecticide development. This class of insecticide is based on the naturally occurring insecticide nicotine (1-A) whose mode of action is to bind to post-synaptic nicotinic acetylcholine receptors. The heterocyclic nitromethylene compound nithiazine (1-B) was one of the first synthetic compounds to exhibit this mode of action. Subsequent structural modifications lead to the development of imidacloprid (1-C), the first commercially available chloronicotinyl insecticide.

The hemlock woolly adelgid, *Adelges tsugae* (Annand), is native to Asia and was introduced to the west coast of North America in the early 1920s. It was discovered in Virginia during the 1950s and has since spread throughout the eastern United States from North Carolina to New Hampshire. The hemlock woolly adelgid completes two generations per year on hemlock. Adults that mature from overwintering nymphs lay 50 to 300 eggs in a cottony white mass on young twigs during March and April. Nymphs hatch during April and May and settle on twigs near the base of the needles where they insert their piercing-sucking mouthparts. The nymphs mature in June and some of the adults of this generation are winged individuals that are unable to reproduce on hemlock. The remainder of the nymphs mature into wingless adults that produce a second generation on hemlock. The nymphs of the second generation hatch in early July and enter a non-feeding dormancy until October when feeding resumes. Nymphs feed and develop during the winter and mature the following spring. Feeding by hemlock woolly adelgid causes the needles on infested branches to desiccate, turn grayish-green, and drop from the tree. Dieback of major limbs can occur within two years and progresses from the bottom of the tree upward. Trees may die within four years, but some survive longer with only a sparse amount of foliage at the very top of the crown (McClure 1995; McClure et al. 2001).

Imidacloprid has been shown to provide excellent control of hemlock woolly adelgid. This paper describes the formulations of imidacloprid that are available to professional applicators and reviews the application techniques that may be used to control this important pest.

Imidacloprid Products Registered for Hemlock Woolly Adelgid Control

Bayer Corporation (Kansas City, Missouri) currently markets two imidacloprid formulations to professional applicators for use in controlling hemlock woolly adelgid. A wettable powder formulation that contains 75% imidacloprid is sold in 2-oz. bottles as Merit[®] 75WP and in water-soluble packets as Merit[®] 75WSP. A flowable formulation that contains 2 lbs. of imidacloprid per gal. (21.4% imidacloprid) is sold as Merit[®] 2F. Each of these three formulations may be applied as foliar sprays or soil treatments.

Two ready-to-use formulations also are available for use as trunk injections. Imicide (J.J. Mauget Co., Arcadia, California) contains 10% imidacloprid and is marketed in capsules that contain either 2, 3, or 4 ml of product. Pointer Insecticide (ArborSystems, LLC, Omaha, Nebraska) contains 5% imidacloprid and is marketed in 4-fluid oz. bottles.

Methods of Applying Imidacloprid for Hemlock Woolly Adelgid Control

There are three methods by which currently registered imidacloprid formulations may be applied for hemlock woolly adelgid control. These are foliar application, soil treatment (drench and high or low volume injection), and trunk injection. Each application method provides excellent control, but the speed of action and duration of residual control varies between these methods.

Traditional foliar application of imidacloprid provides the most rapid activity, but it also has the shortest duration of residual control. Three products are available for foliar application. The Directions for Use section of the Merit® 75WP label states that 1 tsp. (1.4 g) of that product should be mixed with 10 gal. of water for foliar applications targeting adelgids. The Merit® 75WSP label states that one 1.6-oz. packet of that product should be mixed with 300 gal. of water. The Merit® 2F label states that 1.5 fluid ozs. of that product should be mixed with 100 gal. of water. Foliar applications of these products provide excellent, short-term control of hemlock woolly adelgids at dilutions ranging from 28.1 to 39.9 ppm.

Soil treatment with imidacloprid provides the longest duration of hemlock woolly adelgid control, but it also is the slowest acting, and two or more months may pass before acceptable control is achieved. There are three methods by which soil may be treated with imidacloprid. Soil drenches that uniformly apply the desired application rate in no less than ten gallons of water per 1,000 ft² should be directed to the root zone around the base of the tree. High-volume soil injection using hydraulic sprayers with specialized soil injector nozzles may be applied using one of three application patterns. Using the Grid System, injection holes should be spaced on 2.5-ft centers in a grid pattern extending to the drip line of the tree. Using the Circle System, injection holes should be evenly spaced in circles beneath the drip line of the tree and extending inward from that line. The number of circles used depends on the size of the tree. Using the Basal System, injection holes should be evenly spaced around the base of the trunk and the holes should be located 6 to 12 in. from the trunk. The basal system is most commonly used for hemlock woolly adelgid control. Low-volume soil injection may be applied using the specialized Kioritz® injector. This finely engineered piece of equipment applies low volumes (typically 1 fluid oz/in. of tree diameter at breast height) of a highly concentrated dilution of Merit® 75WP using one of the three application patterns described above. Directions for applying Merit® 75WP with the Kioritz soil injector are listed in Table 1. A minimum of four injection sites per tree must be used for each of the soil injection methods.

Calculations for soil treatment with Merit® 75WP using high volume injection or drench applications involve the following five steps:

- 1) Calibrate the sprayer to determine its flow rate in gallons per minute.
- 2) Select an injection volume per inch of tree diameter at breast height.

3) Refer to Table 2 (Injection Times) to determine the amount of time required to deliver the desired volume per injection site. The example highlighted in Table 2 shows that ten seconds are required per in. of tree diameter at breast height when injecting one qt. of solution per site using a sprayer flow rate of 1.5 gal. per minute.

4) Decide how much solution is required.

5) Refer to Table 3 (Fill Rates) to determine the amount of Merit® 75WP that should be mixed in the desired volume of water based on the injection volume identified above. The example highlighted in Table 3 shows that 26.8 ozs. of Merit® 75WP should be mixed in 100 gal. of water when applying the maximum application rate using 1 qt./in. of tree diameter at breast height.

Table 1. Kioritz® Injector Directions For Use

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|----|---|
| 1) | Dilute 2 ozs. of Merit® 75WP in 30 to 60 fluid ozs. of water |
| 2) | Place up to 3 qts. of this dilution into the Kioritz® reservoir |
| 3) | Use the high setting on the Kioritz (5 = 5 ml per stroke) |
| 4) | Apply 1 fluid oz./in. of tree diameter at breast height
(Six strokes delivers approximately 1 fluid oz.) |
| 5) | Use 1 to 2 injection sites per inch of tree diameter at breast height
(Use a minimum of 4 injection sites per plant) |

Table 2. Merit® 75WP Injection Times

Volume per Site	*Sprayer Flow Rate (Gallons per Minute)					
	0.5 gallons	0.75 gallons	1.0 gallon	1.5 gallons	2.0 gallons	3.0 gallons
1 pint	15.0 sec.	10.0 sec.	7.5 sec.	5.0 sec.	3.75 sec.	2.5 sec.
1 quart	30.0 sec.	20.0 sec.	15.0 sec.	10.0 sec.	7.5 sec.	5.0 sec.
2 quarts	60.0 sec.	40.0 sec.	30.0 sec.	20.0 sec.	15.0 sec.	10.0 sec.
1 gallon	120.0 sec.	80.0 sec.	60.0 sec.	40.0 sec.	30.0 sec.	20.0 sec.

* Site = Soil injection site – the selected volume is applied per inch of tree diameter at breast height.

Trunk injection with imidacloprid for hemlock woolly adelgid control may be accomplished using either Imicide® or Pointer® Insecticide (described earlier). Imicide® is typically injected into the root flare of the tree using a self-pressurizing 2 ml capsule. The number of capsules used is a function of the circumference of the tree at breast height. One capsule is used for each 6 in. of tree circumference. Given that Imicide® contains 10% imidacloprid and the specific gravity of the formulation is 1.05, this treatment provides 35 mg of active ingredient per inch of tree circumference. Pointer® Insecticide is typically applied using the Wedgle® injector. The volume of formulation applied is a function of the circumference of the tree at breast height. One ml of

formulation is injected for each 4 to 6 in. of tree circumference. Given that Pointer® contains 5% imidacloprid and the specific gravity of the formulation is 1.073, this treatment provides 8.9 to 13.4 mg of active ingredient per inch of tree circumference.

Table 3. Merit® 75WP Fill Rates

Volume Per Site*	Label Rate Per Inch or Foot	Product Per 100 Gallons	Product Per 50 Gallons	Product Per 25 Gallons	Product Per 10 Gallons	Product Per 1 Gallon
1 Pint	Minimum	26.8 ozs.	13.4 ozs.	6.7 ozs.	2.68 ozs.	0.268 ozs.
1 Pint	Maximum	53.6 ozs.	26.8 ozs.	13.4 ozs.	5.36 ozs.	0.536 ozs.
1 Quart	Minimum	13.4 ozs.	6.7 ozs.	3.35 ozs.	1.34 ozs.	0.134 ozs.
1 Quart	Maximum	26.8 ozs.	13.4 ozs.	6.7 ozs.	2.68 ozs.	0.268 ozs.
2 Quarts	Minimum	6.7 ozs.	3.35 ozs.	1.675 ozs.	0.67 ozs.	0.067 ozs.
2 Quarts	Maximum	13.4 ozs.	6.7 ozs.	3.35 ozs.	1.34 ozs.	0.134 ozs.
1 Gallon	Minimum	3.35 ozs.	1.675 ozs.	0.84 ozs.	0.335 ozs.	0.034 ozs.
1 Gallon	Maximum	6.7 ozs.	3.35 ozs.	1.675 ozs.	0.67 ozs.	0.067 ozs.

* Site = Soil injection site – the selected volume is applied per inch of tree diameter at breast height.

Field Trial Efficacy Data

A number of field trials have been conducted to evaluate the efficacy of imidacloprid against hemlock woolly adelgid. Results from several of these trials will be reviewed to show the level of hemlock woolly adelgid control that can be achieved with foliar, high-volume soil injection and low volume (Kioritz) soil injection with imidacloprid.

Results from a trial that was conducted by Cowles and Cheah (2001) and evaluated traditional foliar application of insecticides are shown in Figure 2. Treatments were applied to the point of runoff on June 6 using a CO₂ pressurized sprayer. Performance was assessed by removing hemlock shoots between June 13 and 18 and counting the nymphs on them using a dissecting microscope. Each of the treatments shown in Figure 2 were applied in combination with the organosilicone surfactant Silwet® L-77 (6.0 fluid ozs. per 100 gal.). The results of this trial show that Merit® 75WP diluted at the rate of 0.5 ozs. per 100 gal. and applied to runoff as a foliar spray provided greater than 98% control of first and later instar hemlock woolly adelgids.

Results from a trial that was conducted by Steward and Horner (1993) which evaluated soil injection of Merit® 2F are shown in Figure 3. Treatments were injected within the dripline of hemlocks using a deep-root feeding gun/nozzle between May 18 and 21. Performance was assessed between October 18 and 26 by randomly sampling five branches from both the bottom and top half of each tree. The first 100 adelgids on the new growth of each branch were examined

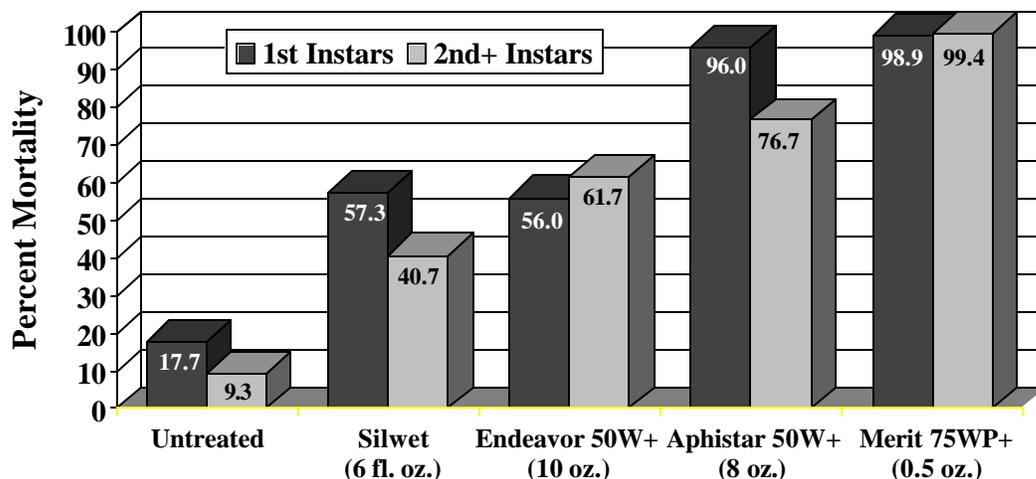


Figure 2. Hemlock woolly adelgid control following foliar application of Merit® 75WP. Value in parentheses is the amount of product per 100 gallons (Cowles and Cheah 2001).

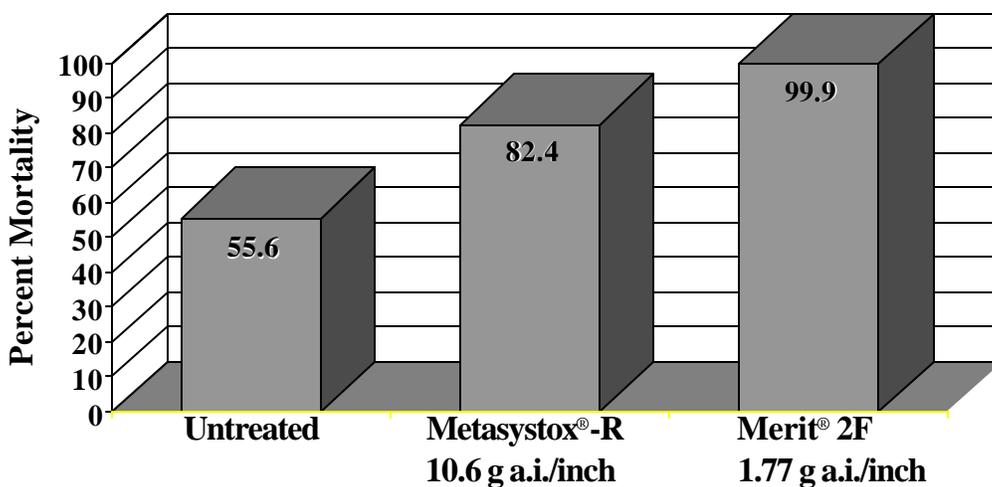


Figure 3. Hemlock woolly adelgid control following soil injection of Merit® 75WP (Steward and Horner 1994).

microscopically and recorded as dead or alive (11,000 adelgids were examined for each of the treatments). The results of this trial show that Merit® 2F soil injected at the rate 1.77 g a.i. per in. of tree diameter at breast height provided greater than 99% control of hemlock woolly adelgids.

Results from a trial that was conducted by Steward et al. (1998) which evaluated soil injection of Merit® 75WP using the Kioritz® soil injector are shown in Figure 4. Treatments were applied by diluting 2 ozs. of Merit® 75WP in 30 fluid ozs. of water and then injecting 1 fluid oz. of this dilution per in. of tree diameter at breast height. This resulted in an application rate of 1.5 g a.i. per in. of tree diameter at breast height. Soil was injected within 1 ft of the root collar at a depth of 6 to 8 in. The soil was treated on November 19, 1996, and performance was assessed almost exactly one

year later on November 20, 1997, by determining the percent of branches that were infested by adelgids. The results of this trial show that Kioritz[®] soil injection of the maximum labeled application rate of Merit[®] 75WP provided greater than 98% control of hemlock woolly adelgids.

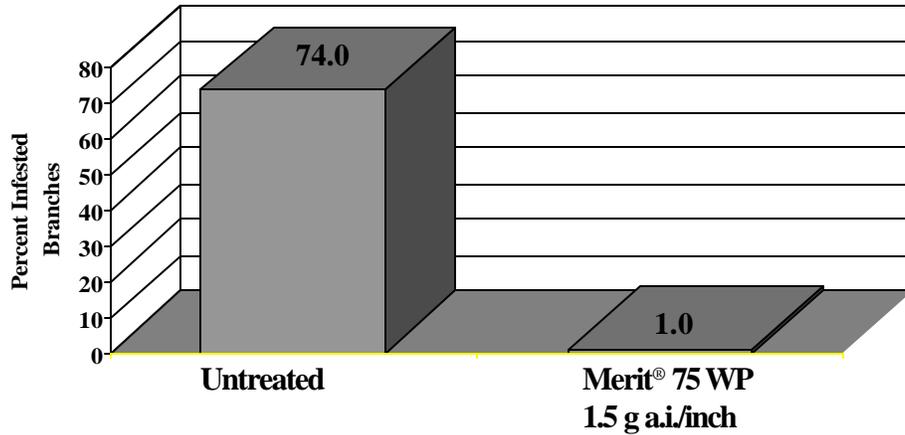


Figure 4. Hemlock woolly adelgid control following Kioritz[®] soil application of Merit[®] 75W (Steward et al. 1998)

Summary

The hemlock woolly adelgid is a serious pest of hemlock from the mid-Atlantic states through much of New England. Several formulations of imidacloprid are available to professional applicators for hemlock woolly adelgid control. Foliar applications of imidacloprid provide the most rapid control, but also have the shortest duration of residual control. Imidacloprid designed for trunk injection generally require a week or longer to provide control, but control will persist for several months. Soil injections of imidacloprid require two or more months to provide control, but these treatments may provide protection for up to two years.

Merit[®] is a registered trademark of Bayer Corporation. Imicide[®] is a trademark of J.J. Mauget Co. Kioritz[®] is a registered trademark of Kioritz Corporation. Pointer[®] and Wedgle[®] are trademarks of ArborSystems, LLC. Silwet[®] I-77 is a registered trademark of OSi Specialties. Specimen labels for the insecticide products mentioned in this article may be obtained from the following websites: www.BayerProCentral.com for Merit[®] 75WP, Merit[®] 75WSP and Merit[®] 2F; www.mauget.com for Imicide[®]; and www.arborsystemsllc.com for Pointer[®].

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