

THE HEMLOCK WOOLLY ADELGID: A THREAT TO HEMLOCK IN TENNESSEE

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The hemlock woolly adelgid (HWA), *Adelges tsugae* (Annand) (Hemiptera: Adelgidae), a destructive aphid-like insect pest of eastern and Carolina hemlock in the eastern United States, is originally from Japan. Its first discovery in the United States was in Oregon on western hemlock in the 1920s. Recent research indicates that HWA is native to this region. It was first detected in the eastern United States in Virginia in the 1950s. Since then it has spread throughout the eastern boundary of the range of eastern hemlocks from Maine south to Georgia. HWA was first discovered in East Tennessee in 2002, and its range has extended into the Cumberland Plateau.

Hemlock species found in Asia and the western and mountain hemlocks that occur in western North America exhibit resistance to HWA; however, the eastern and Carolina hemlocks found in the East are highly susceptible. This pest has caused extensive hemlock mortality in eastern forests.

DAMAGE SYMPTOMS

HWA feeds on all sizes of hemlock, and pest levels can increase rapidly. The insects attach themselves to the base of the hemlock needles and feed from the new twig growth with piercing-sucking mouthparts. The first symptoms are needle yellowing at the tips of branches and needle drop, followed by branch desiccation (drying) and a lack of vigor indicated by a thinning crown. Limb dieback may occur within two years of the initial infestation on seedlings and saplings. Heavily infested larger trees can die within four years, although it may take longer than 10 years depending on proximity to other infested trees, tree size, the level of environmental stress and the quality of the growing site.

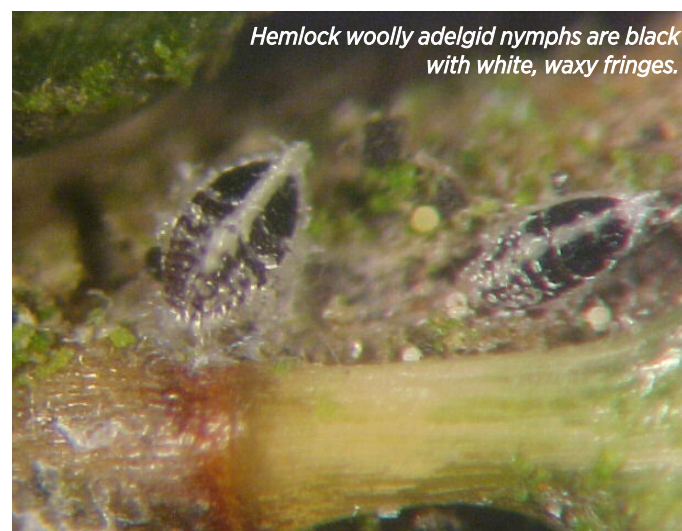
IDENTIFICATION AND LIFE HISTORY

The most noticeable aspect of infested hemlocks is the white “woolly” masses at the base of needles on the twigs. The adults are small (1/32 inch), oval and reddish purple. They are covered with white, fluffy wax tufts of “wool.” This “woolly” material is produced from pores on their bodies. HWA has four life stages: egg, first stage crawler, several nymphal stages and adult. Adults lay a clutch of eggs within a waxy coating called an ovisac. Eggs are initially brownish-orange but will darken as the eggs mature.

HWA has two asexual generations and an unfruitful sexual generation each year. The asexual individuals are female and parthenogenic (adult females reproduce without males by laying eggs that produce females). The first generation (sistens generation) are all female and parthenogenic. They hatch late in the spring and have a nine-month life cycle that allows them to mature and begin laying eggs by midwinter (Cheah et al., 2004). The second generation (progrediens generation) hatches in the early spring and only survives for three months.

The progrediens crawlers quickly develop without a diapause into nymphs and finally two types of adults, winged (sexupara) and wingless offspring (Cheah et al., 2004). The sexupara consists of females and males that have two pairs of wings. They will fly off in search of an alternate spruce host. However, since no suitable spruce host occurs in North America, the sexupara will eventually die without reproducing. Since no mated females are produced on a North American species of spruce, we do not see the characteristic gall in which the mated female's offspring would develop and mature before flying back to a hemlock (Havill et al., 2014).

The wingless progredientes (plural for progrediens) are all female and parthenogenic. They develop on hemlock and when



mature they typically lay small batches of between 30 and 75 eggs in Tennessee. The eggs hatch into flat, reddish-brown sistens crawlers by late spring (Cheah et al., 2004). These crawlers lack a protective waxy covering and actively seek a suitable place to feed near the base of the needles on new growth if available. Once crawlers settle at the base of hemlock needles they do not move; however, they may be dispersed by crawling, wind, birds or other animals before settling.

After settling, the sistentes (plural for sistens) enter diapause (a period of dormancy) during the summer. In the fall they molt into second instar nymphs that are black with a white wax fringe around the edge and down the center of the back. They soon start extruding the “woolly” wax strands that will cover their bodies. The sistentes gradually mature into adults by feeding throughout the fall and into the winter. Beginning in midwinter, the sistentes lay between 50 and 175 eggs (with as many as 300 being observed) that will become the progrediens generation (Cheah et al., 2004; McClure et al., 2001). Low temperatures can kill sistentes in the winter. Although a major mortality factor in the Northeast, cold rarely reduces HWA numbers significantly in the southern US.

CONTROL

Numerous control methods may be used for HWA suppression. In landscape and nursery crop situations, it is practical to rely heavily on chemical control. UT Extension insecticide recommendations for trees in the landscape and nursery are available at ag.tennessee.edu/EPP/Redbook/PB1589.pdf.

In the forest situation, it is much more difficult and expensive to treat all the infested hemlock trees. Forest managers and park officials should make decisions on which trees to treat in

forest settings based on tree stand values, land management objectives, human safety, and the cost of removal of dead trees.

Insecticidal soap and horticultural oil sprays can provide effective control of HWA even when the waxy covering is present. Relative to most other insecticides, insecticidal soaps and horticultural oils have fewer potential adverse effects to the user, with minimal harm to beneficial predators and the environment. Complete coverage is needed for effective control, so a high-pressure spray is necessary for larger trees. A high level of control is possible with just one spray. Evaluate a week after spraying to see if a second spray is needed.

Horticultural oil may cause some phytotoxicity (leaf burn) when applied during the growing season, especially during hot, dry weather. For this reason, a 1 percent solution of horticultural oil is recommended from May through September, while a 2 percent solution can be used from October to April. Insecticidal soap sprays may occasionally cause some phytotoxicity on tender new foliage. It is best to not apply horticultural oil or insecticidal soap if the temperature exceeds 90 F or drops below 45 F. Spraying trees with horticultural oil or insecticidal soap before trees are infested does not act as a deterrent to HWA infestation.

Systemic neonicotinoid insecticides (imidacloprid, thiamethoxam, dinotefuran, acetamiprid) can also be applied as a foliar spray application. Foliar neonicotinoid sprays can be made on trees away from sources of water; however, this method is not commonly used because it does not provide long-term control and poses a greater risk for nontarget impacts. Timing of neonicotinoid sprays is best between mid-May and mid-June and again between late July and October.

Depending on the particular insecticide label, some neonicotinoids can be applied in the root zone as either a soil drench or soil probe injection, injected directly into the tree trunk or sprayed directly on the trunk. The root zone applications or trunk injection methods are much longer lasting than the foliar application, and the level of control is generally better. Imidacloprid has been shown to be effective in suppressing HWA populations for up to seven years. Land managers should begin checking infestation levels in hemlocks five years after treatment. Since imidacloprid does not disperse evenly throughout the hemlock canopy, a few branches may contain HWA while the majority of the branches on the tree have no HWA present. Imidacloprid treatments should be applied when HWA infestations are at low levels on numerous branches sometime between five and seven years after initial imidacloprid treatments were applied.

Root zone applications of neonicotinoid insecticides by soil drenching or soil injection should be made between late August and early December or from mid-March to mid-June. Applying insecticide soil drenches during the summer months or during drought is not recommended. On larger trees, it will take three months for imidacloprid to reach effective concentrations in the hemlock canopy. Dinotefuran will move into the tree much quicker than imidacloprid or thiamethoxam. Moist soil prior to treatment and for seven to 10 days after treatment is needed to optimize uptake. Use rates are determined by the size of the tree trunk. It should be emphasized that trees heavily infested with HWA or those in poor vigor may not be as effectively treated as more vigorous trees. Some but not all of the neonicotinoid insecticides are available at most retail home improvement stores and garden centers. Other neonicotinoid insecticide products are available at landscape, turf or agricultural supply stores.

The trunk injection methods are only available commercially for application by specially trained landscape professionals. The optimal timing of the imidacloprid trunk injections in the spring coincides with egg hatch and crawler attachment to new needles. The best time to apply these injections is one week before through two weeks after leaf out. Tree injection for the fall is timed for September, about a month before partial leaf shed, to control this immature stage.

Dinotefuran trunk sprays are absorbed through the bark and move quickly up the tree to the foliage. This quick uptake makes trunk spray applications comparable to trunk injection in how quickly they control the pest. Dinotefuran will not persist in the tree long enough to give multiple years of control from one application as with imidacloprid and possibly thiamethoxam.



Predatory lady beetle adult, *Sasajiscymnus tsugae*, image courtesy of Carole Cheah, Connecticut Agricultural Experiment Station, Bugwood.org, #1276009.



Predatory lady beetle larva, *Sasajiscymnus tsugae*, image courtesy of Carole Cheah, Connecticut Agricultural Experiment Station, Bugwood.org, #1276007.



INTEGRATED PEST MANAGEMENT (IPM)

While chemical control can be a very useful tool, it is just one component of an IPM approach. IPM uses all available techniques to manage a pest so that economic damage and harmful environmental side effects are minimized. Thus, it is important to prevent the introduction of this pest into new areas. Inspect new landscape or nursery hemlock trees before planting or selling. Use care when moving plants, firewood and other outdoor items from infested areas, especially from March to June when HWA eggs and crawlers may be present.

Maintaining good growing conditions will enhance the survival of hemlocks. Water trees during periods of drought. While applying fertilizer may improve the growth and vigor of uninfested trees, fertilizing with nitrogen enhances HWA survival and reproduction. As a result, a fertilized hemlock becomes more heavily infested and more severely injured than an unfertilized one. Also avoid fertilizing lawn areas within the root zone of infested hemlock trees.

Consider not planting hemlock in or near an infested area and in shady areas, as trees in shade are more susceptible to damage by HWA. Although nothing can replace hemlock in a forest setting, there are a number of evergreens, including pines, spruces, Arizona cypress, Leyland cypress and eastern red cedar, available for landscape use.

BIOLOGICAL CONTROL

The use of biological control beetles is an IPM tactic for HWA suppression. Management of HWA by imported predaceous lady beetles, *Sasajiscymnus tsugae* and *Laricobius nigrinus*, is most effective using an IPM approach for forest stands that includes chemical control. These small black beetles feed almost exclusively on HWA, although they probably will not prevent or eradicate HWA infestations. They are best used in forest situations to help maintain HWA populations at light to moderate levels once established.

S. tsugae has been commercially available in the past, but its availability varies from year to year. Unfortunately, the beetles are expensive and difficult to get established. Beetles often disperse away from the hemlocks on which they were released. While this is not problematic in a forest situation, it is a problem when the goal is to save specific hemlock trees. Biological control using predaceous beetles is ineffective when targeting specific trees. Thus, the use of biological control organisms by individual land owners has been limited and not effective in most cases. In Tennessee, the predominate success so far has been with university or state experts who have the expertise needed to properly release the beetles to best insure their survival. The use of chemical control can maintain hemlock stands until these beetles can become established or until better biological control agents can be discovered and made commercially available. *Laricobius nigrinus* is maintaining pest numbers below damaging levels in areas where it has been released and is well established, but it is not yet available for sale to the public. A promising predaceous beetle being reared at the UT Lindsay Young Beneficial Insects Laboratory is *Laricobius osankensis*, which has been released in limited numbers on public lands.

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