TITLE: **MANAGING THE HEALTH OF HEMLOCKS AT THE MORRIS ARBORETUM**

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ABSTRACT:

Adelges tsuga (Homoptera: Adelgidae), hemlock woolly adelgid (HWA), is an invasive insect pest from Asia that has been affecting the health of native hemlocks, *Tsuga canadensis* and *T. caroliniana*, in the northeast since 1951 in both natural and landscape settings. HWA is the most destructive pests of hemlocks in our area. The first report of HWA at the Morris Arboretum was in the late 1970s, when it appeared sporadically throughout the living collection on *T. canadensis* and *T. carolinana*.

The hemlock collection is an important component of the Morris Arboretum due to its role in the landscape and the tradition of plant exploration. The collection consists of wild-collected material from North America, *T. canadensis* and *T. caroliniana*, and Asia, *T. chinensis*, *T. diversifolia*, and *T. sieboldii*. An evaluation of hemlock health was performed based on tree appearance and presence of pest populations. The HWA life cycle was studied and monitored to determine the best time to control the population. A treatment plan was established and carried out in the fall of 2010 using appropriate control methods. The efficacy of the treatment methods was assessed and the results were used to determine the safest and most effective control for the future management of hemlocks at the Morris Arboretum.

The future management recommendations are based on the results of the project and describe an integrated approach; relying on monitoring, mechanical controls, targeted use of chemical controls, and thorough record keeping to maintain tree health. Within a controlled landscape HWA and other hemlock pests can be controlled to manageable population levels.

Managing the Health of Hemlocks at Morris Arboretum

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BACKGROUND INFORMATION

Tsuga canadensis, eastern hemlock, is an important forest component, growing in almost 19 million acres of northeastern and Appalachian forests (McWilliams and Schmidt 1996), extending from Nova Scotia to Alabama and west to Minnesota. It is a large tree with the potential to reach 140 feet, 3 to 4 feet in diameter and live for 300 to 400 years or more. Hemlocks are commonly restricted to cool, humid climates with adequate moisture, acidic soils, and good drainage, although they can be found growing on drier soils on slopes and ridge tops. *T. canadensis* is extremely shade tolerant, growing in the understory with as little as 5 percent full sunlight (Godman and Lancaster 1990). In northeastern forests, hemlocks are found growing with diverse deciduous trees or in relatively pure stands. In Pennsylvania, eastern hemlock is the state tree growing throughout much of the state. In southern parts of the state hemlock occurs on steep, north-or-east facing slopes along streams. In the northern parts it often occurs in pure stands in moist ravines, stream valleys, and wooded swamps (Rhoads and Block 2005). *T. caroliniana* is limited to the Blue Ridge Mountains of the Southern Appalachians. It is a smaller tree reaching 45 to 60 feet tall.

Mature hemlock forests form a dense evergreen canopy that creates unique environmental conditions critical to terrestrial and aquatic ecosystems. The canopy provides protection from cold winter winds and shade on hot summer days, helping wildlife to save energy. The trees also provide nesting and roosting sites for birds. Some animals that utilize the benefits of hemlock forests include deer, porcupine, snowshoe hare, rabbit, turkey, black-throated-green warbler, rough grouse, blackburnian warbler, acadian flycatcher, solitary vireo, northern goshawk, and aquatics. Hemlock stands are important for stream quality, regulating characteristics such as temperature and stream flow. Hemlock forest-cover along a stream can reduce water temperatures by as much as 4°C (Overton et al. 2010). This unique and irreplaceable quality provides cold pockets for brook trout and macroinvertebrates including mayflies, stoneflies, caddisflies, and salamanders that thrive in cool temperatures.

Hemlocks are beautiful trees, adding charismatic features to the landscape. At the Morris Arboretum the weeping hemlock, *T. canadensis* 'pendula' adds to the serene essence created by the swan pond. A grouping of *T. canadensis* by the log cabin provides shade for visitors on a hot August day and an attractive site for birders. There are 274 named cultivars, making hemlock one of the most cultivated landscape trees in the United States (McClure et. al 1996).

Adelges tsuga (Homoptera: Adelgidae), hemlock woolly adelgid (HWA), is a small aphid-like insect. It feeds by inserting its long hollow sucking mouthparts deep into the base of the hemlock needles. It depletes starch reserves by ingesting the nutrients in the ray parenchyma cells. In response, the tree blocks off the wound created by the insect. This disrupts the flow of nutrients between the twig and its needles, eventually leading to reduced vigor and death of the tree. The decline and eventual death of a hemlock tree following initial infestation may occur within 2 to 12 years. All ages and sizes of trees are susceptible. Stress factors that affect the rate of decline include drought, poor site conditions, and other insect and disease pests such as

elongate hemlock scale (EHS) and spruce spider mite, both of which are present at the Arboretum.

The first report of HWA in northeastern North America was in Richmond, Virginia in 1951 in a private plant collection. It was discovered in southeastern Pennsylvania in 1969, and quickly became a serious pest in both forest and landscape settings. Scientists have discovered a direct link between HWA in eastern North America and southern Japan. The insect appears to have arrived on nursery stock (Havill and Montgomery 2008). HWA is not a severe pest in its native range because of abundant and effective natural predators that reduce infestation levels.

Today, the infestation of HWA in the eastern United States ranges from northeastern Georgia to Southern Maine and westward to eastern Tennessee. Populations of HWA have been expanding rapidly throughout the natural range of hemlock at an estimated rate of 20 to 30 km per year (McClure et al. 1996). Vectors include wind, wildlife, humans, and transport on infested nursery stock.

Some limitations to HWA survivorship exist. Natural mortality of North American populations is found to be 37.3 to 68.7 percent annually (McClure et al. 1996). Very cold temperatures reduce population size. A case study in Connecticut showed that after a temperature of -5°F HWA population declined by 90 percent. Optimizing hemlock growing conditions is showing significance in the management of pest levels. Yet HWA is adapting and being protected by snow coverage. It is anticipated that as hemlock mortality continues, stands will be replaced by deciduous species that will have ecological impacts on terrestrial and aquatic ecosystems.

MATERIALS AND METHODS

To manage the health of hemlocks at the Morris Arboretum 70 trees were chosen for monitoring, treatment, or to act as controls. Fifty-five (55) high priority trees were the treatment group and 15 low priority trees comprised the control group. All 70 trees were monitored to observe adelgid development, population levels, and tree appearance. The results of comparing treated trees to non treated trees, post-treatment, established a baseline for evaluating the efficacy of treatments. Also, information was collected pretreatment on HWA population levels to be compared to post treatment HWA population levels. It was not possible to actually make this comparison because the treatment uptake time exceeds the time limit of my project. All information is recorded for future use.

In September each tree was evaluated for population density of hemlock pests (HWA, EHS and mites) and tree appearance (needle color, canopy density, and new shoot growth). HWA was evaluated by counting the number of adelgid on a 10 inch branch containing current year's growth up to 10 individual adelgids, this is repeated 10 times for each tree. This resulted in a maximum possible value of 100 adelgids per tree sample, or 100 percent infestation (Cowles 2010). HWA and EHS were recorded as a level of pest population: absent, light, moderate, or heavy. Absent, when no individuals were found, light when population was 1-20 percent,

moderate when population was 21-60 percent, and heavy when population was 61-100 percent. After evaluation and consultation with local experts the following treatment options were selected: Safari, Merit, Safari and horticultural oil or Merit and horticultural oil. Horticultural oil and the systemic insecticides, Merit and Safari, have varying specifications for targeted pest, ecological impact, uptake, and residual time.

In October the targeted treatments were conducted following the *Morris Arboretum of the University of Pennsylvania Policy on Pest Management and Pesticide Use* and *Material Safety Data Sheets* for specified chemicals. The treatment took a total of three days to complete. The even distribution of the chemical throughout the tree, or at the tree base during application, aids in equal absorption and best results. In the following winter months HWA was reevaluated on treated and non treated hemlocks using the method described above.

As another means of tree health evaluation, pictures were taken upward through the canopy of hemlock stands using a wide angle lens. Gap Light Analyzer (GLA) software was employed to analyze canopy structure and calculate light penetration or percentage of canopy openness. The assumption is that canopy openness and light penetration are directly correlated with needle loss and canopy degradation due to HWA. Three stands: the log cabin, Widener woods and Meadowbrook Avenue, represented hemlock canopies that have been threatened by HWA. The canopy at Pastorius Park represents hemlocks free of HWA. These trees have received ongoing treatment since 1998 and have been free of HWA for several years.

RESULTS AND DISCUSSION

Hemlock woolly adelgid population levels of the treatment and control group were compared to determine treatment efficacy. HWA population levels were significantly lower among the treatment group compared to the control group as seen in Figure 1. The median of the control group was 93 percent infested, the median of the treatment group was 5 percent infested. Within the treatment group the range between minimum and maximum populations is 0 percent to 22 percent, a fairly narrow range. The higher end of the treatment group represents the results of Merit while the lower range was Safari. Over an extended period of time a greater difference among the treatment types would be expected due to varying chemical specifications such as absorption rates and residual time. Safari would be expected to show almost immediate decline in pest populations. Over a longer period of time Safari would soon provide less protection from infestation. Merit would be expected to show a slower yet steady and more persistent decline of infestation levels. A larger sample size and random assignment of treatments might have produced a wider range of results.

The Gap Light Analyzer (GLA) provided data on canopy density at four sites. Canopy density is greatest at Pastorius Park allowing less light penetration compared to trees at the other three sites that are currently infested with HWA and have been for years, as seen in Figure 2. Arborist working at Pastorius Park informed that the hemlocks there had been free of HWA for over five years. There is great significance in the density of hemlock canopies especially when considering its ecological role to terrestrial and aquatic ecosystems.

The HWA population levels on species of hemlock vary according to their geographic origin. Chinese species *T. chinensis* and Japanese species *T. divesifolia* show resistance to HWA. Native species, *T. canadensis* and *T. caroliniana,* and Japanese species, T. *sieboldii* show susceptibility as seen in Figure 3.

See Appendix for Result Figures and Data.

CONCLUSION AND MANAGEMENT RECOMMENDATIONS

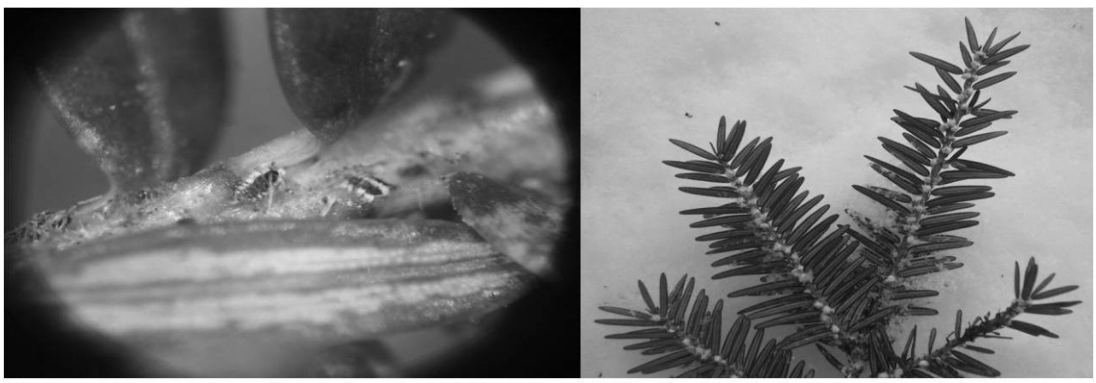
At the Morris Arboretum, North American species: *T. canadensis* and *T. caroliniana* show the greatest susceptibility to hemlock woolly adelgid while most Asian species show high resistance. If native *Tsuga* species are to remain a part of the Morris Arboretum living collection, it is imperative to manage level of pests, especially HWA. This can be accomplished by scouting to monitor health and the targeted use of chemical controls.

The hemlock pest scouting form, stored on the shared drive S:\Morris\General\NoBackUps\IPM\HemlockRecord.xlsx, can be used yearly to record and communicate information on pests and treatment status. Treatment options have variable absorption, residual timing, and environmental impacts. All of which need to be considered while choosing the treatment method. Also keep in mind that alternating treatment chemicals may become necessary if pests develop a resistance.

Scouting and Evaluating

The *Hemlock Pest Scouting Form* can be used yearly to record and communicate information on pests and treatment status. Data should include identification of present pests, pest population levels, and tree appearance; reflecting needle color, canopy density, and shoot growth. This data will be used to understand the health of the tree and to make further decisions about chemical or manual control. Monitoring is most effective when conducted periodically throughout the year. When scouting for HWA in the fall a hand lens is required to see the small sistens at the base of the current year's needle. In the winter or early spring white woolly masses are easily visible. These identifications are depicted in the image below.

Cultural Practice



(Left image) Sistens at base of hemlock needle, (right image) adult HWA with white woolly ovasic

Studies completed by Longwood Gardens, Nathan Havil and others have shown improved hemlock health by reducing invasion of HWA and improving growing conditions. Reducing infestation can be done by selecting appropriate trees and branches for removal to decrease the inoculum of HWA. While transporting infested material, caution needs to be taken to avoid further dispersal of HWA, this is especially important in March while the HWA is in the crawler stage. Also, avoid intentionally attracting wildlife into hemlock trees. Avoid placing bird feeders in or near hemlock trees to decrease dispersal via birds.

Improve growing conditions by ensuring 1 inch of water/per week within the drip line of the tree (this includes rainfall), removing dead wood, providing organic matter greater than 4 percent, avoiding nitrogen fertilization, maintaining soil pH between 4 to 5, and reducing soil compaction.

T. chinensis and *T. diversifolia* are highly resistant and suitable to conditions at the Arboretum. The planting of these trees is encouraged while research and improvements are made to overcome HWA. It is also encouraged to be alert for resistance within wild collections and varieties of native plants.

Planning Chemical Treatment

Chemical control is an essential component in using an IPM approach to reduce and control the population of hemlock pests including HWA. Chemicals should be used only in the response of an infestation. Trees should be prioritized to maintain a manageable pest level, appropriate cost, and overall best management practice.

Treatment options have variable absorption, residual timing, and environmental impacts. All of which need to be considered while choosing the treatment method. Alternating treatment chemicals may become necessary if pests develop a resistance.

Table 1: Treatment Option Information						
Product	**Product application**	**Target Hemlock Pest**	**Time for Uptake**	**Residual**	**Environmental and Human Impacts**	**Cost**
Safari (Dinotefuran)	Systemic insecticide, soil drench	HWA, EHS	3-6 weeks	Up to 2 years	Water soluble, greater water quality impacts, highly toxic to bees	$$
Merit (Imidacloprid)	Systemic insecticide, soil drench	HWA	1-12 months	Up to 7-8 years	Low mammalian toxicity	$
Horticultural Oil (Petroleum Oil)	Foliar spray	HWA, EHS mites	On contact, "suffocation"	none	Relatively safe to applicator, beneficial insects and environment, toxic to fish	$

Timing is very important in the control of hemlock pests. Typically horticultural oil should be applied twice each year in early spring and late fall to target each generation. The amount and concentration should be one percent mixture in the spring and two percent mixture in the fall. It is found to be most effective when used in the spring, directly after 100 percent egg hatch, estimated to occur in our region between 505 and 676 GDD using Base50. Refer to life cycle in Appendix.

Continuous record keeping is very important. Each year records are to be entered into an Excel spread sheet named HemlockRecord.xlsx document, found in the shared drive: S:\Morris\General\NoBackUps\IPM\HemlockRecord.xlsx

See Appendix for detailed information on identification, treatment options and spread sheet.

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APPENDIX A: Treatment Details

The following paragraphs provide detailed information on the treatment for the control of hemlock pests at the Morris Arboretum.

Imidicloprid-Merit

Merit is a systemic insecticide; its active ingredient is imidicloprid. Merit targets HWA and other sucking insects, it does not control spider mite or EHS. It is applied as soil injections and is actively transported into the tree through the roots. When the chemical reaches the feeding site of the adelgid it paralyzes and kills the pest. Merit works best when applied in the fall or spring, in moist soil and cool air temperatures. Merit takes 6 weeks to 12 months or longer to become effective. Control of HWA on new shoot growth may be seen within a few years, residual time is 7 to 8 years (Dalusky 2010). Residual time is based on observations made by US Forest Service, Forest Entomologist at University of Georgia and other sources. It is convoluted to quantify a residual time for any treatment because of several factors including the rebound time for HWA to reestablish, winter weather and unknown natural pressures facing HWA recovery. An unresolved issue with Merit is unequal absorption of the chemical throughout the tree, causing the effect to be spotty throughout the canopy. This can be minimized by administering the chemical equally at several around the trunk at a depth of 6 inches below the soil surface.

Dinotefuran-Safari

Safari is a systemic insecticide; its active ingredient is dinotefuran. It targets HWA, EHS, and spider mites. It is applied as a soil drench. It is more water soluble then Merit and moves more quickly through the tree, within 3 to 6 weeks; its residual is approximately 2 years. However, Safari is more expensive and has greater potential to affect water quality of near-by streams (Dalusky 2010). Safari is found to work best when rapid control is needed, such as when trees have no new shoot growth, significant needle loss, badly thinning canopy, and/or dead lower branches.

Horticultural Oil

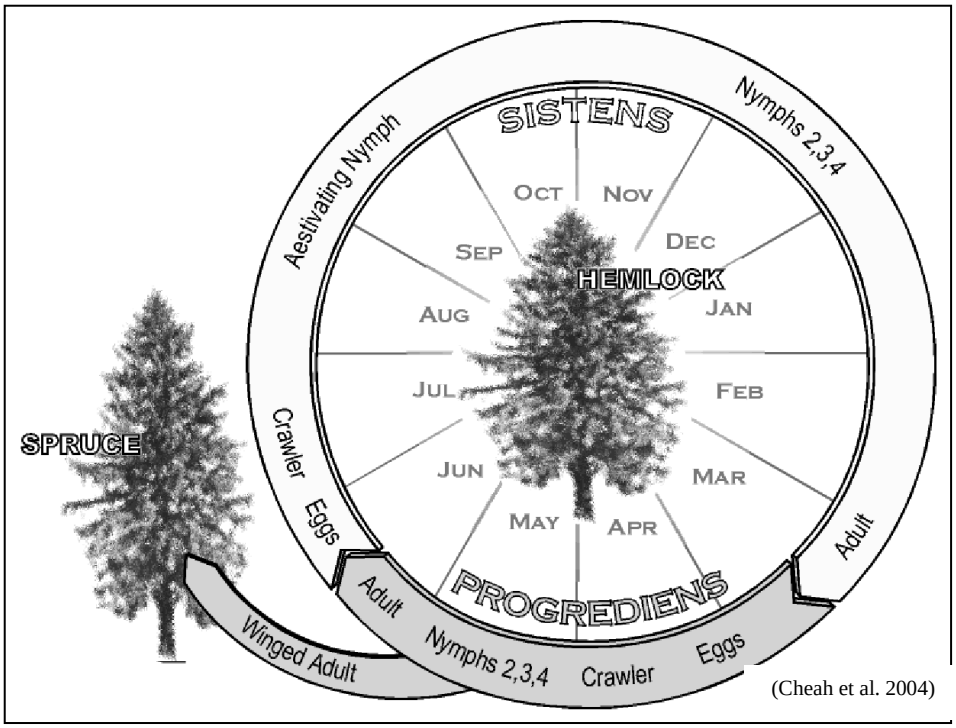
Horticultural oil is a foliar spray, smothering and killing insects on contact. A miticide is sometimes added to reduce the possibility of an increase in mite populations after treatment of HWA.

Biological Control

Predators for HWA are a target of several biocontrol programs in the eastern United States. Progress is being made with rearing *Pseudoscymnus tsugae* Sasaji and three Scymnus sp. In Trenton, New Jersey the Phillip Alampi Beneficial Insect Rearing Lab is known for high quality work and the pursuit of difficult tasks. Currently a small team of dedicated scientists are working to rear *Laricobius nigrinus* (Coleoptera: Derodontidae), a beetle predator of HWA. Native to Ohio, this strain is cold hardy, unlike other *L. nigrinus* that have been reared and released in New Jersey and Virginia. *L. nigrinus* has a narrow host range and has been cleared for field release by USDA APHIS and NAPPO in 2000; they have been released at 22 sites in 8 states. Phillip Alampi Lab continues to test new species and strains to ultimately build a matrix

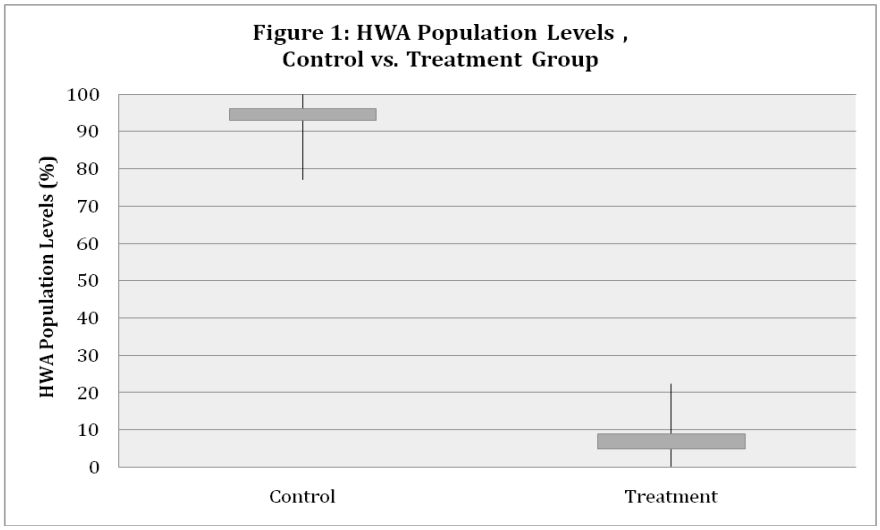
of natural enemies that will contribute to the suppression of HWA. Beneficials are currently not a reliable source of control for the Morris Arboretum hemlocks because of multiple factors including cost, availability, and use of chemical controls. With more research and funding this option may become more available and manageable.

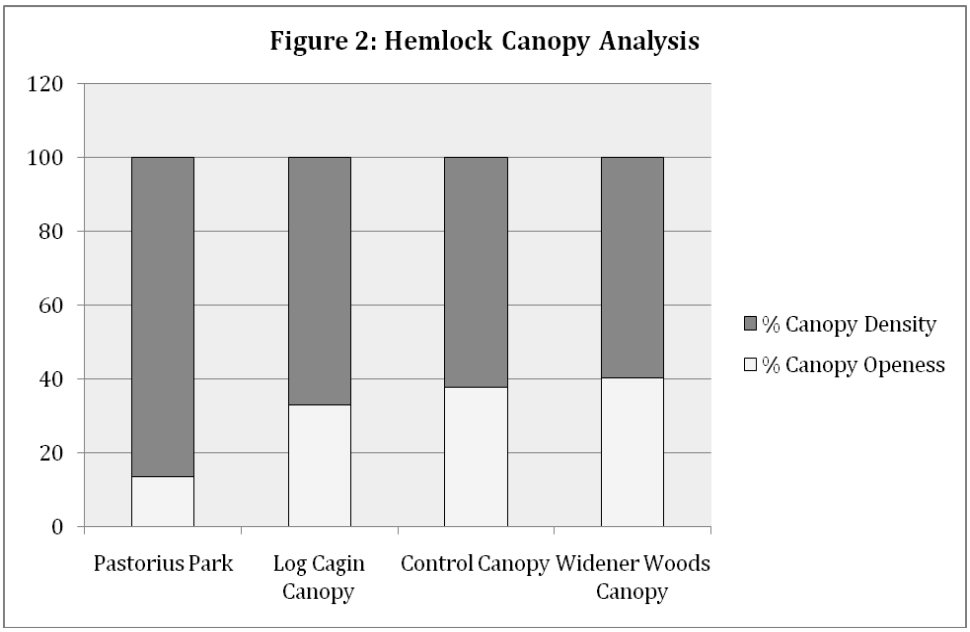
APPENDIX B: HWA Life Cycle as a Guide to Treatment Timing

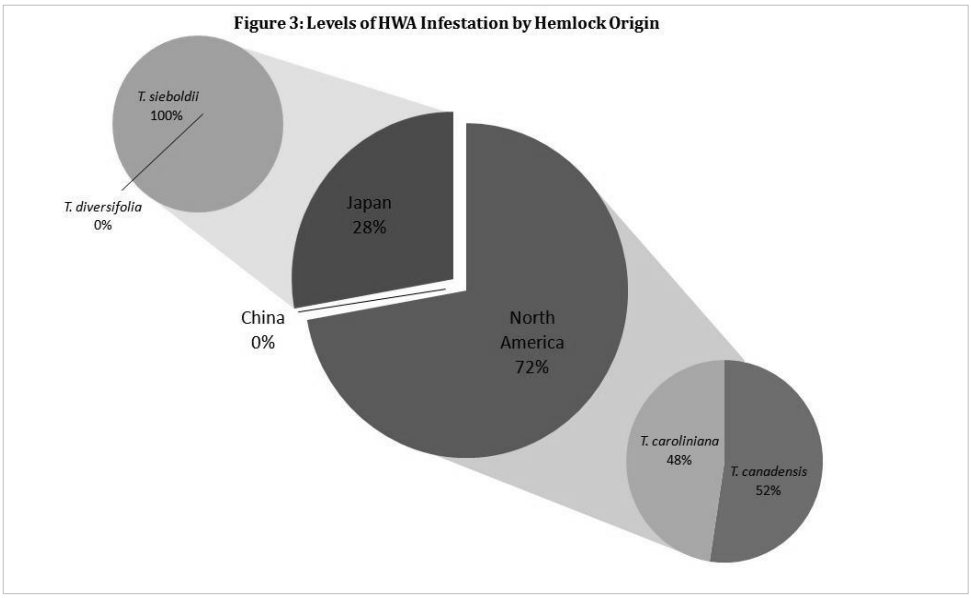


The image above depicts HWA life cycle in Georgia, eastern Pennsylvania zone is cooler and cycle is expected to be shifted slightly clockwise. Highly suggested foliar spray time is after 100 percent egg hatch in spring, estimated to occur between 505-675 GDD.

APPENDIX C: Result Figures







Oct 2010														Jan 2011			
Tree Type	Location	Accession #	Priority	HWA	EHS	Mites Present	Appearance	DBH (inches)	Treated(Y or N)	Date	Product/Method	Product/Method	Observation:	HWA			
Tsuga canadensis	G5	2000-393*A	high	moderate	moderate	no	good	13.38583	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		moderate			
Tsuga canadensis	G5	2000-394*A	high	moderate	moderate	no	good	17.42126	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		moderate			
Tsuga canadensis	J6	2002-203*A	high	heavy	moderate	no	good	20.96457	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga canadensis f. pendula	G21	32-0672*A	high	absent	light	no	good	29.52756	yes	Oct-10		safari/soil injection		absent			
Tsuga canadensis 'Albospica'	G22	32-0673*A	high	moderate	moderate	no	good	35.43307	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		absent			
Tsuga diversifolia	G22	32-0674*A	high	absent	light	no	poor	23.22835	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		absent			
Tsuga canadensis	J19	32-0774*A	high	moderate	moderate	no	good	36.22047	yes	Oct-10		safari/soil injection	Tree too tall to reach with spray hose	moderate			
Tsuga canadensis	H19	32-0775*A	high	moderate	moderate	no	good	50	yes	Oct-10		safari/soil injection	Tree too tall to reach with spray hose	light			
Tsuga canadensis f. pendula	L19	32-1044*A	high	absent	absent	no	good	22.6378	no					absent			
Tsuga sieboldii	E21	32-1499*A	high	moderate	moderate	no	poor	30.70866	yes	Oct-10		safari/soil injection		absent			
Tsuga sieboldii	B20	32-1731*A	high	moderate	moderate	no	poor	21.85039	yes	Oct-10		safari/soil injection		heavy			
Tsuga canadensis	J20	35-6124*EE	high	heavy	light	no	poor	25.98425	yes	Oct-10		merit/soil injection	Tree too tall to reach with spray hose	absent			
Tsuga canadensis	J20	35-6124*KK	high	heavy	light	no	poor	22.14567	yes	Oct-10		merit/soil injection	Tree too tall to reach with spray hose	absent			
Tsuga canadensis 'Bristol's Shortleaf'	J7	35-6504*A	high	moderate	heavy	no	good	20.47244	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		absent			
Tsuga canadensis 'Bristol's Shortleaf'	G18	35-6504*B	high	moderate	light	no	good	19.29134	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga diversifolia	E21	35-6510*A	high	absent	absent	no	good	15.35433	yes	Oct-10		merit/soil injection		absent			
Tsuga canadensis 'Macrophylla'	H18	39-8509*A	high	moderate	moderate	no	poor	32.28347	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		moderate			
Tsuga canadensis	H19	39-8510*A	high	moderate	moderate	no	good	27.55906	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			

Tree Type	Location	Accession #	Priority	HWA	EHS	Mites Present	Appearance	DBH (inches)	Treated(Y or N)	Date	Product/Method	Product/Method	Observation:	HWA			
Tsuga sieboldii	H21	44-059*A	high	moderate	moderate	no	good	24.40945	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga canadensis	H19	45-128*A	high	moderate	moderate	no	good	37.40158	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		absent			
Tsuga canadensis	H19	45-129*A	high	heavy	moderate	no	good	27.55906	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga canadensis	H19	45-131*A	high	heavy	moderate	no	good	38.97638	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		moderate			
Tsuga canadensis	F20	48-823*A	high	heavy	moderate	no	poor	25.59.055	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection	Tree by log cabin close to stream, do not use Safari; caution with spray drift	light			
Tsuga canadensis	F20	48-823*C	high	moderate	light	no	poor	20.86614	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection	Tree by log cabin close to stream, do not use Safari; caution with spray drift	light			
Tsuga canadensis	F20	48-823*D	high	moderate	light	no	poor	18.50394	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection	Tree by log cabin close to stream, do not use Safari; caution with spray drift	absent			
Tsuga canadensis	F20	48-823*E	high	moderate	light	no	poor	21.25984	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection	Tree by log cabin close to stream, do not use Safari; caution with spray drift	light			
Tsuga canadensis	F20	48-823*G	high	moderate	light	no	poor	13.77953	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection	Tree by log cabin close to stream, do not use Safari; caution with spray drift	moderate			
Tsuga canadensis	F20	48-823*H	high	heavy	moderate	no	poor	15.35433	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection	Tree by log cabin close to stream, do not use Safari; caution with spray drift	light			

Tree Type	Location	Accession #	Priority	HWA	EHS	Mites Present	Appearance	DBH (inches)	Treated(Y or N)	Date	Product/Method	Product/Method	Observation:	HWA			
Tsuga chinensis	D21	48-883*A	high	absent	light	no	good	21.45669	yes	Oct-10		merit/soil injection		absent			
Tsuga canadensis 'Saratoga Broom'	H20	49-499*A	high	light	absent	no	good	18.11024	yes	Oct-10		merit/soil injection		moderate			
Tsuga canadensis	F20	54-0645*A	high	moderate	light	no	poor	22.44095	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga canadensis	F19	54-0645*B	high	moderate	light	no	poor	17.32284	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga diversifolia	G18	54-0894*A	high	absent	light	no	good	27.75591	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		absent			
Tsuga canadensis var.	J6	75-118*A	high	moderate	light	no	good	21.85039	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga sieboldii	J7	75-126*A	high	absent	light	no	good	22.6378	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		absent			
Tsuga canadensis 'Macrophylla'	E20	78-059*A	high	moderate	moderate	no	poor	15.15748	yes	Oct-10		safari/soil injection		absent			
Tsuga chinensis var. formosana	F22	81-283*A	high	absent	light	no	good	11.7126	yes	Oct-10		safari/soil injection		absent			
Tsuga chinensis var. formosana	F22	81-284*A	high	absent	light	no	good	13.38583	yes	Oct-10		safari/soil injection		absent			
Tsuga chinensis var. formosana	F22	81-285*A	high	absent	light	no	good	15.74803	yes	Oct-10		safari/soil injection		absent			
Tsuga canadensis	F5	82-098*A	high	moderate	light	no	good	27.46063	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga caroliniana	H18	94-101*A	high	moderate	light	no	poor	10.5315	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		absent			
Tsuga caroliniana	H17	94-102*A	high	moderate	moderate	no	poor	9.64567	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-017*A	high	heavy	moderate	no	poor	8.956693	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		moderate			
Tsuga canadensis	H16	97-019*A	high	moderate	moderate	no	poor	9.448819	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-020*A	high	moderate	heavy	no	poor	13.18898	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-021*A	high	moderate	moderate	no	poor	10.23655	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-022*A	high	light	moderate	no	poor	12.5	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		absent			
Tsuga canadensis	H16	97-023*A	high	heavy	light	no	poor	7.874016	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		absent			

Tree Type	Location	Accession #	Priority	HWA	EHS	Mites Present	Appearance	DBH (inches)	Treated(Y or N)	Date	Product/Method	Product/Method	Observation:	HWA			
Tsuga canadensis	H16	97-024*A	high	heavy	heavy	no	poor	5.413386	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-025*A	high	moderate	heavy	no	poor	8.858268	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-026*A	high	heavy	heavy	no	poor	5.905512	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-031*A	high	moderate	moderate	no	poor	10.9252	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-047*A	high	moderate	moderate	no	poor	8.661418	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		moderate			
Tsuga canadensis	E21	35-6124*AA	low						no,control								
Tsuga canadensis	A19	35-6124*B	low						no,control					high			
Tsuga canadensis	E21	35-6124*BB	low						no,control					high			
Tsuga canadensis	A19	35-6124*C	low						no,control					high			
Tsuga canadensis	F17	35-6124*S	low						no,control					high			
Tsuga canadensis	B19	48-823*EE	low						no,control					high			
Tsuga canadensis	B19	48-823*FF	low						no,control					high			
Tsuga canadensis	B19	48-823*HH	low						no,control					high			
Tsuga canadensis	B19	48-823*JJ	low						no,control					high			
Tsuga canadensis	K21	48-823*L	low						no,control					high			
Tsuga canadensis	K21	48-823*MM	low						no,control					high			
Tsuga canadensis	B20	48-823*NN	low						no,control					high			
Tsuga canadensis	B20	48-823*OO	low						no,control					high			
Tsuga canadensis	H17	97-011*A	low						no,control					high			
Tsuga canadensis	H17	97-013*A	low						no,control					high			