Possible Use of Field Insectaries to Rear Hemlock Woolly Adelgid Predators

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Abstract

Suppression of the hemlock woolly adelgid (HWA), *Adelges tsugae* Annand (Homoptera: Adelgidae), in the Eastern United States has focussed on several predators as biological control agents. Three have been released and large numbers of each species will be needed for additional releases. Current rearing programs of predators of the HWA in the laboratory require an abundance of prey that may be scarce at critical times. As predators generally require a larger food base than parasitoids, the success of any rearing program depends on the availability of an adequate source of prey to sustain their populations. We propose that field insectaries be explored for propagation of HWA predators to supplement lab-rearing programs.

Keywords:

Hemlock woolly adelgid, field insectary, rearing HWA predators.

Introduction

Biological control is being emphasized as a management tactic in restricting the spread of the HWA in the Eastern United States. The classical concept involves the successful establishment of self-sustaining populations of exotic predators released for HWA control, and their subsequent dispersal. Since large numbers of predators are needed for release to cover the entire range of eastern hemlock, field procedures in addition to laboratory rearing should be investigated. Laboratory rearing have been initiated for three coleopteran predators, *Pseudoscymnus tsugae* Sasaji and McClure (Coccinellidae), *Scymnus* (*Neopullus*) *sinuanodulus* Yu et Yao (Coccinellidae), and *Laricobius nigrinus* Fender (Derodontidae). Although some success in lab propagation of these species has been reported, their full potential cannot be realized because of the seasonal lack of HWA to sustain the colonies. Thus, propagation of these predators should be supplemented by field rearing through the use of insectaries.

Concept of a Field Insectary

A field insectary is the rearing of living insects under field conditions by manipulation of resources to favor multiplication but not dispersal. This technique is suitable for rearing host specific insects but

not for generalists as the latter can easily find an alternate food source and move out of the area. The objective is to establish and maintain a large self-sustaining population of the desired insect that can be collected for relocation to new field sites. To achieve this, we need to provide an abundance of resources for the insect to complete development and multiply. An optimal predator/prey ratio has to be determined and maintained to discourage it from leaving in search of another richer resource patch. Once an estimate of the predator/prey ratio is known, excess insects can be collected and removed from the insectary. For host specific predators, a field insectary has to be large enough to support an abundance of the prey population for the predator to avoid population pressure leading to its dispersal.

Documented Successes of Field Nurseries/Insectaries in Biological Control

Reports of use of field nurseries/insectaries for rearing of predators, parasitoids, and weed biological control agents have been well documented, but few have been in the forest ecosystem (Table 1). Successful examples are the use of field nurseries for propagation of *Trichosirocalus horridus* (Panzer) (Coleoptera: Curculionidae) for *Carduus* thistle control (Stoyer and Kok 1986); field cages for propagation of *Agapeta zoegana* L. (Lepidoptera: Cochylidae) in biological control of spotted knapweed, *Centaurea maculosa* Lam. (Story et al. 1994); field nursery cages in rearing parasitoids of the diamondback moth, *Plutella xylostella* L.(Lepidoptera: Plutellidae) in cabbage (Hu et al. 1998); field nursery areas for water-hyacinth, *Eichhornia crassipes* (Martius) Solms-Laubach weevils (Manning 1979); and field nursery for the parasitoid *Tetrastichus julis* (Wlk.) of the cereal leaf beetle *Oulema melanopus* (L.) (Coleoptera: Chrysomelidae) (Logan et al. 1976). One report relating to forestry is use of field nursery for detection of natural enemies of *Cinara piceae* (Panz) (Hom: Lachnidae), a pest of young European fir trees, *Abies alba* Mill. (Stary 1976). Some examples of current institutional users of field insectaries are the USDA program for control of leafy spurge, *Euphorbia esula* L. (Euphorbiaceae) in Montana, http://www.team.ars.usda.gov/symposium/1995/seven.html; Colorado Department of Agriculture program for musk thistle (*Carduus thoermeri* Weinmann) control, http://www.ag.state.co.us/DPI/publications/leafyspurge.html; and Missouri Department of Agriculture Greenley Field Insectary program for cereal leaf beetle control, http://aes.missouri.edu/greenley/fieldday/page21.stm.

At Virginia Tech, successful establishment of field insectaries for thistle weevil production has allowed us to continue distribution of the weevils for about two decades, long after our field collection sites have been depleted by the successful control of the target weeds. We resorted to the use of field insectaries as thistle populations in our field sites declined. Thus, there is precedence for the use of field insectary for propagating biological control agents, and there is no reason why this cannot be extended to predators of HWA. We describe in the following steps that we have taken to establish a field nursery for *L. nigrinus* in Blacksburg, Virginia. Our objective is to demonstrate the potential of such field insectaries for any HWA predator that needs mass propagation.

Table 1. Some Examples of Field Nursery/Insectary for Rearing Natural Enemies.

Ecosystem	Natural enemy	Prey	Reference
Pasture	*Trichosirocalus horridus* (Panzer) Curculionidae) Weinmann (Crown feeder)	*Carduus. thoermeri* (Musk thistle)	Stoyer and Kok 1986 (Coleoptera:
Rangeland	*Agapeta zoegana* L. (Lepidoptera: Cochylidae) (Root borer)	*Centaurea maculosa* Lam. (Spotted knapweed)	Story et al. 1994
Aquatic	*Neochetina eichhorniae* Warner and *Neochetina bruchi* Hustache (Coleoptera: Curculionidae) (Leaf/petiole feeder)	*Eichhornia crassipes* (Martius) Solms-Laubach (Waterhyacinth)	Manning 1979
Agriculture	*Tetrastichus julis* (Wlk) (Hymenoptera: Eulophidae) (Larval parasitoid)	*Oulema melanopus* (L.) (Coleoptera: Chrysomelidae) (Cereal leaf beetle)	Logan et al. 1976
Agriculture	*Cotesia plutellae* Kurdj (Hymenoptera: Braconidae) (Larval parasitoid)	*Plutelia xylostella* (L.) (Lepidoptera: Plutellidae) (Diamondback moth)	Hu et al. 1998
Agriculture	*Diadegma insulare* (Meus.) (Hymenoptera: Ichneumonidae) (Larval/pupal parasitoid)	"	"
Forest	*Didea fasciata* Macquart (Diptera: Syrphidae) (Predator)	*Cinara piceae* (Panz.) (Homoptera: Lachnidae) (Bark aphid)	Stary 1976

Procedures for Establishment of Field Insectaries for HWA Predators

Factors to be considered to establish field insectaries are size of insectary and site selection, provision of a steady and reliable food base, host plants for HWA infestation, predator/prey ratio, and labor and costs.

Site Selection and Size of Insectary

Site selection is important as this has an influence on the establishment and dispersal of the predators. The first requirement is that it must be easily accessible and within an hour of driving distance from the research base. Partial isolation is required to ensure that the released predators do not move out of the area in search of HWA in natural stands of hemlocks nearby. Thus, the selected site should not have large stands of hemlock in its immediate vicinity. Ideally, each field insectary should be divided into three equal parts to be planted with hemlocks in three consecutive years. This is to ensure that at least three years of sequential plantings will be available for sustaining HWA and its predators. The size of the field insectary must be sufficiently large to accommodate the predators, but not too large to make it difficult to manage.

Our current field insectary is about 0.5 hectare, with potential for extension. The land has been divided into blocks 10 m apart (Figures 1a and 1b). Within each block, hemlock saplings are planted 3 m apart. We have identified two adjacent areas for expansion of the insectary

Planting and Infesting Hemlocks with HWA in Field Insectary

Step two involves planting of the insectary with hemlock saplings. This is the most labor-intensive part of the project. Once the planted hemlocks have survived the transplanting shock, the next step is to infest them with HWA. In our field insectary at the Kentland Farm in Montgomery County, Virginia, we purchased and planted 300 young hemlock trees, 2 to 3 m tall, in the fall of 2001. The use of young trees is based on our successful initial collection of *L. nigrinus* from hemlock seed orchards in British Columbia, Canada. The hemlocks in the seed orchard are small enough and the branches with HWA are within easy reach for search of *L. nigrinus*. This enables the branches to be beaten or shaken to dislodge predators among the HWA. As we have been collecting from this seed orchard for six consecutive years, it appears that the young hemlocks are able to support a population of HWA and *L. nigrinus*.

If we can duplicate the British Columbia seed orchard in Virginia, we need not have to depend on further collections in Canada. We also have planted about 200 yellow poplar, *Liriodendron tulipifera* L. (Magnoliaceae), whips (1 m tall), 0.7 m apart, to provide shade for some of the hemlocks. In spring 2002, we will collect HWA-infested twigs and tie them to the remaining non-infested hemlocks. Several of the planted young hemlocks were already infested with HWA.

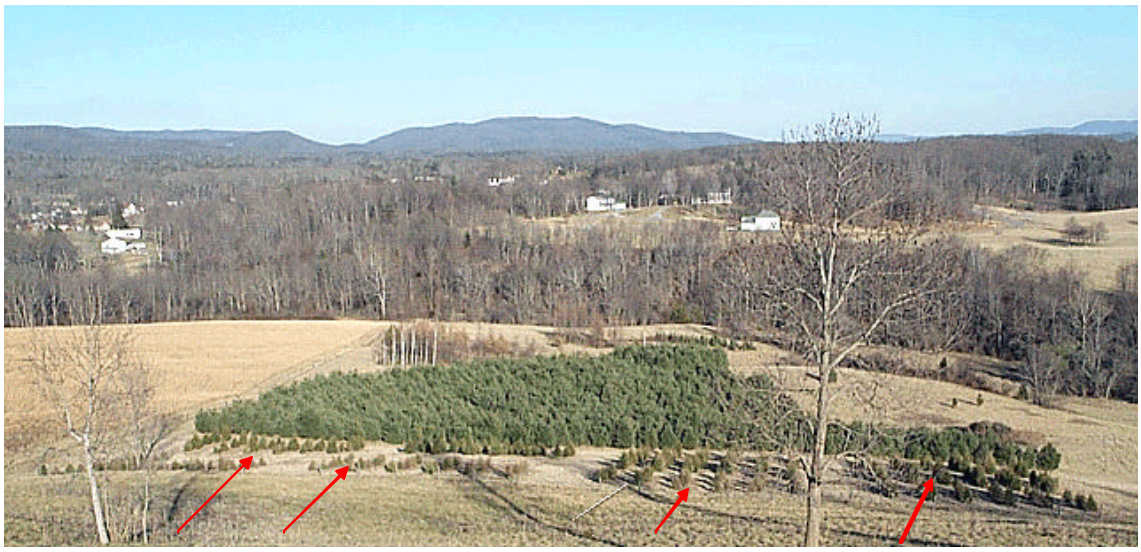

Figure 1a. Photo by J. Fidgen.

Figure 1b.

Figure 1. Field insectary at Kentland Farm, Montgomery County, Virginia; **(a)** arrows indicate current plots viewed from a distance; **(b)** close-up view.

Establishment of HWA Predators

Following infestation and establishment of HWA on the hemlocks in the field insectary, predators should be released. Success in establishment of the predators depends on an adequate supply of HWA, and thus the optimal predator/prey ratio needs to be determined. It is important that the number of predators released in each insectary should not overwhelm the HWA population, as the concept is to enable the predators to reproduce and increase their numbers in the field insectary. The subsequent planting of the second and third phases of the insectary is to ensure that the planted hemlocks can be infested in sequence.

In our field insectary, we plan to release *L. nigrinus* on the HWA-infested trees in 2002. Our data indicate that about 226 HWA eggs would support the complete larval development of each *L. nigrinus,* and an adult feeds on 16 eggs per day (Salom et al. 2001). Thus, the estimated predator/ prey ratio that we would be using for *L. nigrinus* is about 1: 330 HWA eggs, assuming that the adults are allowed to feed for a week after emergence before being collected. The predator/prey ratio will depend on the species, e.g., for *Scymnus sinuanodus,* a fourth instar eats about 90 eggs per day and each adult over a 30-day period consumed about 49 nymphs per day (Salom et al. 2001). Thus, *S. sinuanodus* will need a larger prey number because of its higher prey consumption than *L. nigrinus.*

Collection of HWA Predators

The primary aim of the field nursery is to ensure a self-sustaining steady supply of predators that can be collected for distribution and released in new identified field sites with high levels of HWA infestation. Removal of HWA predators would help to maintain the appropriate predator/prey ratio in the field insectary.

Advantages of Field Insectaries

There are several advantages to the establishment of field insectaries over laboratory rearing. The main advantage is that it is not as labor intensive as laboratory rearing, which requires close supervision and daily management of the colony. Because insects in field insectaries are exposed to more natural conditions, survival of the predators would not be limited by artificial laboratory conditions, such as interruptions caused by equipment failure, power outage, lack of food at critical times (e.g., HWA sistens during the winter months), or lack of supervision during extended seasonal holiday periods. Thus, mass rearing of insects is generally more successful under field conditions and more economical than laboratory rearing.

Disadvantages of Field Insectaries

There also are some problems associated with use of field insectaries. A major limitation is that we have no control over environmental conditions in the field, and less security for limiting trespassers.

Also, we cannot monitor the insect population as closely as can be done in the laboratory. Cost of establishment also is high initially as land and plants have to be available or bought; and there is a large input of labor for land preparation, planting, and irrigation of the hemlock trees.

Cost of Establishment of a Field Insectary

Besides the availability of land for the field insectary, the major expense is in the cost of hemlock and shade trees and labor involved in land preparation, planting, and mulching of the planted trees. For example, in our field insectary the cost of a healthy 2 to 3 m hemlock sapling is about $35 to $42 each, with the added cost of about $5 to $6 per tree for transportation. Thus, cost of 300 trees including transportation is about $12,000 (average of $40 per tree including transportation), with an additional $100 for 200 yellow poplar whips @ $0.50 each. We were able to get a discount for the hemlock saplings because a few of them were infested with HWA. We paid only $26 each, totaling $7,800. There was no charge for mulch as this is available from Virginia Tech.

Labor for land preparation, digging large holes for the balled tree seedlings, unloading, planting trees, and mulching amount to about 600 man-hours. This would total $9,000 at an average cost of $15 per hour. Thus, initial outlay for a 0.5 ha insectary in the first year would require a minimum of $16,900, excluding the cost of land. Additional costs after planting include those associated with laying irrigation pipes, estimated at $1,200 (necessary as in the case of an unusual dry spell after our planting). Year 2 and 3 costs would have to be included if the insectary is expanded. If successful, the self-sustaining nature of field insectaries would still be less than the cost of hiring a full-time lab technician specifically for laboratory rearing.

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