ASSESSMENT OF EGG RELEASES FOR ESTABLISHMENT OF *SASAJISCYMNUS TSUGAE* ON EASTERN HEMLOCK

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ABSTRACT

Infestations of the hemlock woolly adelgid, *Adelges tsugae* Annand (Homoptera: Adelgidae), are now regularly found on eastern hemlock, *Tsuga canadensis* (L.) Carriere, in the Great Smoky Mountains National Park. Management programs have been implemented to reduce the impact of this exotic pest on hemlocks. One management tool has been to release an exotic predatory lady beetle, *Sasajiscymnus* (=*Pseudoscymnus*) *tsugae* (Sasaji and McClure), which feeds on hemlock woolly adelgid. Unfortunately, rearing programs to produce large numbers of adult *S. tsugae* are labor intensive and expensive. Thus, alternate release plans (e.g., egg releases) are under investigation to maximize production capacity and minimize inputs. Egg releases would save time, effort, and money. This paper summarizes results of the first year of this multi-year study to assess egg releases as a means to establish *S. tsugae*. Results supported the use of egg releases for field establishment of *S. tsugae* against hemlock woolly adelgid, as eggs hatched, immatures developed through all life stages, and adults were recovered. The timing of egg releases with suitable prey stages is critical and imperative to the successful survival and colonization of *S. tsugae*. Suitable food must be present at the time of release, as well as several weeks after release. Further research will better clarify optimum release conditions and contribute to a more defined release protocol to enable forest resource managers to enhance release and establishment of *S. tsugae* against hemlock woolly adelgid on eastern hemlock.

KEYWORDS

Sasajiscymnus tsugae, biological control, predator, *Tsuga canadensis*, *Adelges tsugae*.

INTRODUCTION

The health and survival of eastern hemlock, *Tsuga canadensis* (L.) Carriere, are now threatened by the hemlock woolly adelgid, *Adelges tsugae* Annand (Homoptera: Adelgidae), a small aphid-like insect introduced into the United States from Japan and China. Knauer et al. (2002) listed the hemlock woolly adelgid as the single greatest threat to the health and sustainability of hemlock as a forest resource in eastern North America. In the forests of the southern Appalachians, eastern hemlock is an important component and is widely distributed. More than 1,500 ha of hemlock-dominated forests are found in the Great Smoky Mountains National Park (GRSM), and some of these trees are more than 400 years old (Johnson 1995). Of the more than 100 native tree species in GRSM, the eastern hemlock is the only species of hemlock known to occur within its boundaries (Taylor 2002). Eastern hemlock is ecologically and environmentally important as a forest component and is a dominant species in at least five of the 12 vegetation types in GRSM (Taylor 2002).

Unfortunately, management tools are limited in an entire forest, considering its area and diverse systems. Although insecticides may save individual trees, area-wide chemical control is impractical or not economically feasible in the forest. No native natural enemies or pest-resistant eastern hemlocks have been found, but exotic biological control agents have been identified as potential mortality agents of hemlock woolly adelgid (Butin et al. 2002, Cheah and McClure 1996, 1998, 2000, McClure 1995, McClure et al. 2000, Montgomery and Lyon 1996, Wallace and Hain 2000). One of these organisms, a lady beetle, *Sasajiscymnus* (=*Pseudoscymnus*) *tsugae* (Sasaji and McClure), has been released against hemlock woolly adelgid in numerous states (Blumenthal 2002, Casagrande et al. 2002, Cheah and McClure 2002, McClure and Cheah 2002). The release of *S. tsugae* in newly-infested areas, such as the GRSM, before the adelgid becomes widely distributed may lower the adelgid's ability to reach highly damaging levels.

Rearing programs to produce large numbers of adult *S. tsugae* are labor intensive and expensive. Thus, the development and implementation of alternate release plans (e.g., egg releases) would maximize production capacity and minimize inputs. Releases of eggs at field sites would be a tremendous boost to rearing programs by saving time, effort, and money. A multi-year research project was initiated to assess the potential success and benefits of alternative strategies to release and establish *S. tsugae* on eastern hemlock. This research focuses specifically on egg releases and includes the following objectives: 1) develop protocols for egg releases of *S. tsugae* to augment the regional biological control effort, 2) evaluate incidence and establishment of *S. tsugae* one year after field release, and 3) assess development, survival, and colonization of *S. tsugae* released as eggs against hemlock woolly adelgid in sleeve cages in the field. This paper summarizes results of the first year of this study.

MATERIALS AND METHODS

Before the initiation of this project, discussions were held with numerous individuals with experience working with large-scale insect rearing programs or with *S. tsugae*. Based on these

discussions and previous research results (specifically, those presented in Palmer and Sheppard 2002), protocols were developed to acquire and maintain large numbers of eggs for shipment (obtained from the New Jersey Department of Agriculture), laboratory confinement, and placement in the field. Eggs were shipped via overnight mail and placed in the field on the day they were received.

In 2003, egg releases of *S. tsugae* were made at two locations (Jakes Creek, 16 trees, and Meigs Creek, six trees) by park personnel in the GRSM. Eggs were placed in the field on April 24 at Jakes Creek (4,000 eggs) and on May 22 at Meigs Creek (5,000 eggs). Post-release evaluations (visual examinations, sweep-net samples, and branch collections evaluated in the laboratory) were conducted several months and one year after egg releases.

In a separate study to investigate the development and survival of *S. tsugae* on eastern hemlock, twigs and gauze containing eggs (ca. 6,500) of *S. tsugae* were placed on twigs using twist ties and covered with screened sleeve cages. Eggs were placed in 21 sleeve cages (ca. 250 eggs/cage) in the field on April 22, 2004, at Elkmont. As a control treatment, eggs also were placed on twigs of eastern hemlock in jars (3.8 l) and maintained in incubators in the laboratory. Three cages were removed each week for seven weeks and taken to the laboratory where the contents were examined thoroughly; the number of damaged and nondamaged woolly masses were counted to assess predator activity. Development and survival of *S. tsugae* in the control jars also was monitored weekly for comparison. Data analyses were performed using SPSS® (2002) to assess differences among seasonal survival and development of beetles.

RESULTS AND DISCUSSION

Low numbers (fewer than 10) of larvae and adult beetles were found several weeks after release at both Jakes Creek and Meigs Creek locations in 2003. However, no larvae or beetles were recovered at either location one year post-release, in 2004. These results were somewhat consistent with adult beetle releases in which predator recovery was low in subsequent years (P.L. Lambdin, unpublished data). Tree health and adelgid vigor and quality on release trees were extremely poor in 2004; these characteristics are not conducive to beetle viability. Results also suggested that the initial egg releases in 2003 may have been made too late in the season for developing beetles to have sufficient food (i.e., crawlers) for an extended duration.

Sleeve cage evaluations suggested that egg releases of *S. tsugae* provide a viable means to attempt to establish populations of this predator. Eggs hatched and all larval instars developed including prepupa and pupa. Adults were recovered (though in low numbers), suggesting that trees could be colonized via egg releases of *S. tsugae*. Poor adelgid quality or lack of suitable stages may have affected adult development.

Predatory activity of larvae on adelgids within sleeve cages was evident. About 43.9% of all woolly masses on twigs inside cages were damaged by *S. tsugae*. Comparatively, only 19.1% of woolly masses held as controls in the laboratory exhibited similar damage. Although these masses were disturbed or damaged, many nondamaged eggs remained. Percentage of damaged woolly masses in the field peaked at 64.9% after five weeks (Table 1).

Adelgid crawlers were numerous when this research was initiated on April 22, and had been extremely abundant earlier. On the release date, crawler densities averaged approximately 15.5/2.5 cm of twig length. Unfortunately, densities fell sharply (ca. 93%) one week later and remained almost nonexistent during the remainder of the study (Figure 1). Because adelgid eggs and crawlers provide nutritional resources for beetle larvae, the low numbers of these prey probably impacted the numbers of beetles that developed successfully to adulthood. In the sleeve cages where suitable prey was unavailable, cannibalism of *S. tsugae* on prepupae and pupae was observed. This cannibalism could adversely affect colonization and establishment of this predator.

SUMMARY

These results are encouraging as they support the use of egg releases of *S. tsugae* for field establishment against hemlock woolly adelgid. Eggs hatched, immatures developed through all life stages, and adults were recovered. It is important to also assess the feasibility of releasing early-instar larvae, which are not as vulnerable to predators and not as susceptible to temperature/climatic fluctuations. As this preliminary assessment demonstrates, timing of egg and larval releases with suitable prey stages is critical and imperative to the successful survival and colonization of *S. tsugae*. Suitable food must be present at the time of release, as well as several weeks after release, for beetle development. Adelgid eggs, in general, are suitable food for larvae of *S. tsugae*. However, in this study, many adelgid eggs were available but were unacceptable as food for *S. tsugae* and never hatched. The reasons for these non-viable and unacceptable eggs are unclear. Further research will better clarify optimum release conditions and contribute to a more defined release protocol. Improved methodologies will enable forest resource managers to release and establish *S. tsugae* over a wider geographical area to reduce populations of hemlock woolly adelgid on eastern hemlock.

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Table 1. Weekly assessment of damaged and nondamaged woolly masses in sleeve cages during seven weeks after field placement.

Week No.	No. Damaged Woolly Masses	No. Nondamaged Woolly Masses	% Damaged Masses
2	2.91 + 0.30 a*	2.80 + 0.54 b	51.0
3	3.10 + 0.28 a	3.83 + 0.46 b	44.7
4	2.60 + 0.30 a	3.22 + 0.29 b	44.7
5	3.11 + 0.22 a	1.68 + 0.19 a	64.9
6	1.48 + 0.28 b	3.43 + 0.43 b	30.1
7	1.77 + 0.24 b	5.11 + 0.43 c	25.7

* Numbers within a column followed by the same letter are not significantly different (p=0.05).

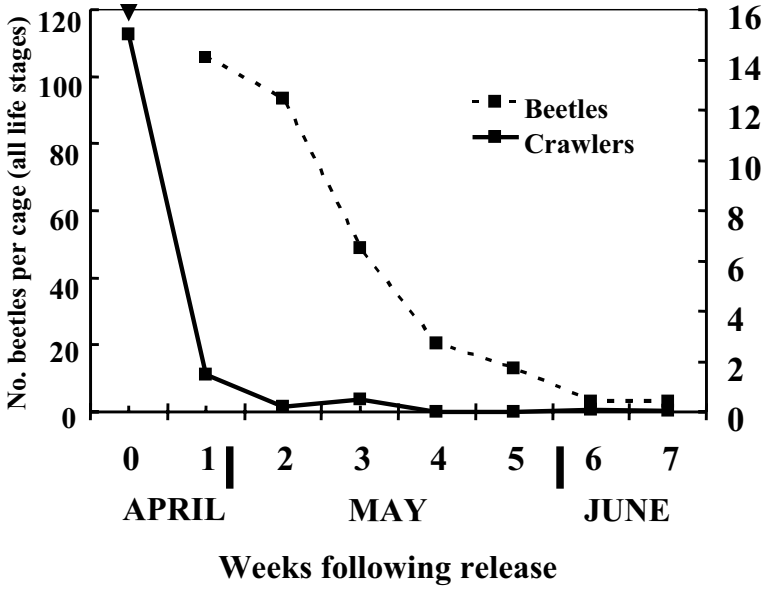

Figure 1. Weekly assessment of predator and adelgid activity in sleeve cages for seven weeks following egg release, Great Smoky Mountains National Park, 2004.

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