Implications of Preventing the Induction of Diapause in Hemlock Woolly Adelgid

Scott M. Salom

Department of Entomology, Virginia Tech
Blacksburg, VA 24061-0319

Abstract

One of the main problems in mass rearing predators of HWA is maintaining productivity while HWA undergoes aestival diapause. Cold storing HWA-infested hemlock branches prior to the induction of diapause is one possible way of making up for the food shortage. Another way is to use live HWA-infested hemlocks and manipulate the maternal generation (progrediens) of the diapausing sistens to avoid the induction of diapause. The resulting continuous development of HWA should theoretically provide a continuous source of food for predators. Scenarios for integrating continuous rearing of HWA for use in mass rearing are presented.

Keywords:

Adelges tsugae, biological control, mass rearing, predators, diapause.

Introduction

The use of host specific predators to help regulate hemlock woolly adelgid (HWA) *Adelges tsugae* Annand (Homoptera: Adelgidae) populations is being studied intensively by several research groups in the United States (Salom et al. 2001a). The predators include *Pseudoscymnus tsugae* (Coleoptera: Coccinellidae) Sasaji and McClure (Sasaji and McClure 1997; Cheah and McClure 1998); *Scymnus* (*Neopullus*) *sinuanodulus* Yu et Yao (Coleoptera: Coccinellidae) (Lu and Montgomery 2001); and *Laricobius nigrinus* (Coleoptera: Derodontidae) (Zilahi-Balogh 2001; Salom et al. 2001a). Once the potential biological control agents have been adequately studied in the lab, it is necessary to mass rear them in preparation for their field release. It is only at this time that true evaluation of the predator's attributes in relation to its host can be made. This involves evaluation of the field establishment of the predator and its impact on the target pest species.

The importance of mass rearing cannot be underscored. The difficulty and complexity of providing an adequate food source for biological control agents is summarized by Etzel and Legner (1999). In rearing hosts, they state that difficulty decreases from living plants; harvested plant parts; tubers, fruit and other produce; and prepared diets. HWA essentially sticks to the tissue it feeds on. The adelgids are specific tissue feeders, using stylets to suck the contents of storage parenchyma cells below the abcission layer of hemlock needles (Young et al. 1995). They would die if pulled from the plant. Therefore, it is necessary to cut HWA-infested twigs from trees and place the predators on the twigs to feed and oviposit on. No work has been done to determine if an artificial diet could be used to rear any of the HWA predators. This would be a useful direction of research. In the meantime, we must rely on the use of HWA-infested branches.

Some shortcomings associated with using live adelgids on cut twigs include the difficulty of finding infested material close by the rearing facility; the relatively short storage time of cut material for retaining live HWA, unless a walk-in cold room is available; and the long aestival period of first instar sistens.

Finding Host Material

If you are rearing predators in the heart of HWA infestations, then all that is required is driving with a pickup truck or van to a forest setting, cutting numerous branches of infested material, and heading back to the lab for processing. This often needs to be done once or twice a week. However, if the mass-rearing facility is nowhere near active infestations, a long driving distance may be required. Individuals at rearing facilities have occasionally had difficulty finding infested branches, either because of low spring populations or because the infestations have passed the facility by. At times this has required colleagues from other regions to mail infested material to the lab.

Storage Time

Field collected branches can be placed in buckets of water and the material can retain enough moisture at room temperature for up to two weeks. Thereafter the branches begin to dry up. Lu and Montgomery (2001) placed infested branches in buckets of water and stored the material in a cold room held at 5°C. When removed from the cold room, the infested material was kept at 10 to 15°C for about 2 weeks before being fed to the predators. Using this approach, live sistens eggs were available as a food source for predators for up to 5 months.

HWA Diapause

Sistens go into aestival diapause for ca. 4 months beginning in June and lasting into October (McClure 1989; Gray and Salom 1996). *Pseudoscymnus tsugae* has been reported to feed on aestivating sistens but stop reproducing (D. Palmer, personal communication). *Scymnus sinuanodulus* has been found associated with and feeding on other adelgid species in China, perhaps to help the beetles survive during their maturation feeding period (M. Montgomery, personal communication). *Laricobius nigrinus* goes into aestival diapause over a similar time period as HWA, however, this past year at Virginia Tech, adult *L. nigrinus* emerged from diapause more than 2 months before HWA did, leaving little food for the beetles. Eastern spruce-gall adelgids *(Adelges abietis* L.) nymphs were used for feeding, but their supply is highly variable and their effect on the colony is not fully known.

Salom et al. (2001b) reported that aestival diapause in HWA is facultative and can be avoided by exposing critical lifestages to specific environmental conditions. They determined that egg stage to second instar progrediens (maternal generation of aestivating sistens) needs to be continuously exposed to temperatures ranging from 12 to14.5°C and a photoperiod of 12:12 (L:D). Thereafter, HWA could be exposed to temperatures up to 17°C to continue development. This results in the continuous development of sistens without the interruption of diapause.

The problem of providing a food source for predators when HWA undergoes aestival diapause requires further investigation. The use of a cold room to store HWA-infested branches for the duration of the sistens diapause may turn out to be an adequate approach. Where access to a large cold storage room is limited or where HWA infestations are a considerable distance away, an alternative is to consider the use of live HWA-infested hemlocks and to manipulate the progrediens lifestage for about 2 weeks to prevent the induction of diapause. My lab intends to evaluate both strategies in the future and assess the relative difficulties and successes in rearing predators on hosts using both approaches. In the following present two scenarios that focus on rearing HWA through the normal aestival diapause period with the objective of providing a continuous source of food for predators.

Scenario 1. I will use our own current situation with *L. nigrinus* and describe the procedure we will carry out to prevent diapause from occurring in HWA sistens. This will theoretically allow for a continuous food source for *L. nigrinus* when they emerge from diapause. Between 300 and 400 4-year-old potted hemlock seedlings will be placed in a cool room at 14°C and a 12:12 (L:D) photoperiod. They will be placed under a rack of grow lights to make sure the seedlings remain healthy. When sistens ovisacs are full of eggs and ready to hatch crawlers in local field settings, twigs will be clipped from these trees and attached to twigs of the noninfested seedlings in the cool room. The seedlings will become infested and progrediens will develop on the seedlings. Weekly sampling of lifestages will commence. When a majority of progrediens have reached second instar, half the seedlings will be moved outside into a cool, shaded lathe house and the remaining seedlings will remain inside under the controlled conditions in the cool room. Lifestage development will continue to be monitored at both locations. When sistens eggs hatch and crawlers settle, they should continue to develop rather than go into diapause. If *L. nigrinus* emerges from aestival diapause early as in 2001, then the new adults will have live and actively developing preferred prey to feed upon.

Scenario 2. *Pseudoscymnus tsugae* does not go through aestival diapause. But it becomes reproductively inactive for the 4 months that HWA normally aestivates. If it is provided with an adequate supply of actively developing HWA, it could continue to produce progeny, resulting in increased predator production. Since this situation requires food for 4 months rather than 2, as in Scenario 1, considerably more food is needed. Three options are recommended: cold storing cut branches as described by Lu and Montgomery (2001); increasing the number of potted seedlings to be infested and manipulated; or using larger potted trees that can sustain substantially more HWA. Whatever approach is chosen, a fairly large cold room or cool room will be required to work with the increased volume of material.

Manipulating HWA on potted seedlings in order to provide a food source for predators when HWA normally aestivates is no small task. However, since the environmental conditions for preventing the induction of aestival diapause in sistens nymphs have been identified, it is just a matter of working out the details of making this a part of an operational rearing program. We will report in the future as to the success of this proposed effort.

References

Etzel, L.K., E.F. Legner 1999. Culture and colonization, pp. 125-197. In Bellows, T.S. and T.W. Fisher (eds.). *Handbook of biological control*. San Diego: Academic Press.

Gray, D.R., S.M. Salom. 1996. Biology of hemlock woolly adelgid in the southern Appalachians, pp. 16-25. In Salom, S.M., T.C. Tigner, and R.C. Reardon (eds.). *First Hemlock Woolly Adelgid Review*, 12 October 1995, Charlottesville, Virginia. U.S. Department of Agriculture, Forest Service, Morgantown, West Virginia.

Lu, W. and M.E. Montgomery. 2001. Oviposition, development, and feeding of *Scymnus (Neopullus) sinuanodulus* (Coleoptera: Coccinellidae): a predator of *Adelges tsugae* (Homoptera: Adelgidae). *Annals of the Entomological Society of America.* 94: 64-70.

McClure, M.S. 1989. Evidence of a polymorphic life cycle in the hemlock woolly adelgid, *Adelges tsugae* (Homoptera: Adelgidae). *Annals of the Entomological Society of America*. 82: 50-54.

Salom, S.M., M.S. McClure, M.E. Montgomery, G. Zilahi-Balogh, and L.T. Kok. 2001a. Hemlock woolly adelgid in the United States: status of ongoing biological control research, pp. 87-97. Protection of world forests: advances in research. In Alfaro, R., K. Day, S. Salom, A. Liebhold, H. Evans, F. Lieutier, M. Wagner, K. Futai, K. Suzuki, and K.S.S. Nair, (eds.) *IUFRO World Series Vol. 11*. IUFRO Secretariat, Vienna, Austria.

Salom, S.M., A.A. Sharov, W.T. Mays, and J.W. Neal, Jr. 2001b. Evaluation of aestival diapause in hemlock woolly adelgid. *Environmental Entomology*. 30: 877-882.

Sasaji, H. and S.M. McClure. 1997. Description and distribution of *Pseudoscymnus tsugae* sp. nov. (Coleoptera: Coccinellidae), an important predator of hemlock woolly adelgid in Japan. *Annals of the Entomological Society of America*. 90: 563-568.

Young, R.F., K.S. Shields, and Berlyn. 1995. Hemlock woolly adelgid (Homoptera: Adelgidae): stylet bundle insertion and feeding sites. *Annals of the Entomological Society of America*. 88: 827-835.