Given the significance of SPB and MPB as recurring forest pests, the unprecedented expansion of their geographic ranges, colonization of novel hosts, and the difficulties associated with forest level management, it's clear that gene silencing could provide a powerful tool for tomorrow's bark beetle management.

Temperature effects on spotted lanternfly phenology

Melody A. Keena[a], Devin Kreitman[b], Anne Nielsen[c], and George Hamilton[b]

[a] USDA Forest Service, Northern Research Station, Hamden, CT

[b] Rutgers, The State University of New Jersey, Brunswick, NJ

[c] Rutgers Agricultural Research & Extension Center, Rutgers, The State University of New Jersey, Bridgeton, NJ

Abstract

Lycorma delicatula (White) (spotted lanternfly [SLF]), an invasive planthopper from Asia, is an emerging pest in North America. Good phenology models based on the responses of SLF to a broad range of temperatures are needed for predicting when monitoring for SLF needs to be done, when the right stage is present for application of control methods, and what regions of the US are likely to support SLF populations. This information is also needed to develop protocols for rearing large numbers of SLF for use in bioassays or biological control rearing. Without an efficient laboratory rearing methodology for SLF, mass rearing of any discovered natural enemies needed for field testing or release will be limited, especially outside the infested zone. Efforts to screen pesticides are equally restricted by the resources needed to obtain the large numbers of even aged individuals from natural populations. Year-round mass rearing would allow rapid screening of many pesticides and other monitoring or control methods.

SLF has one generation per year in Korea with nymphs emerging in May and adults appearing in July. Similar occurrence of life stages is observed in Pennsylvania; nymphs begin to emerge in late April, and adults appear around mid-July and lay eggs from early September until first frost (Dara et al. 2015). Little is known about SLF responses to temperature and the only modeling on potential range was done for Korea using CLIMEX and the current range information for populations in Korea (Jung et al. 2017). Egg survival of SLF is associated with winter temperature (Lee et al. 2014) and in laboratory rearing experiments, egg hatch occurs at 56, 27, and 22 days at 15, 20, and 25°C, respectively. Degree-day (DD) requirements for egg hatch were estimated to be 355 $DD_{8.14}$ (Choi et al. 2012), but no information on biofix is included. Thus, it is currently unknown at what temperatures egg hatch can occur or if SLF uses specific environmental cues to time hatch, such as photoperiod or chilling days. For example, SLF egg hatch was observed in Winchester, VA by D. Pfeiffer on May 9, 2018 which is 266 $DD_{8.14}$ using the parameters from available studies. This suggests that evaluation of egg hatch and nymphal development of the US population is needed to develop precise phenological models and

predict seasonality. The timing of egg hatch is the biofix needed to start the phenology model and the conditions needed could potentially restrict the range of this insect.

Ninety-six egg masses of SLF from five locations in Pennsylvania were obtained in the beginning of April and hatched by the end of May 2019 for use in the nymphal phenology studies. Six groups of 20 SLF each were setup on tree of heaven, *Ailanthus altissima* (Miller), seedlings in tubes at each temperature and were observed daily for mortality and molts. SLF was reared from first instar to adult on *A. altissima* at each of the following constant temperatures: 5, 10, 15, 20, 25, 30, 35, and 40°C. The time spent in each instar and mortality were recorded. For the egg hatch studies, newly laid SLF eggs (<14 d old) from three Pennsylvania sites were collected in October 2019. The egg masses were held at three constant temperatures (10, 15, or 20°C) or exposed to low (5 and 10°C) temperatures for 0, 7, 28, 56, or 84 d followed by incubation at 25°C while maintaining the photoperiod of 16:8 (L:D).

The lower threshold for egg development was estimated as 7.39°C. Eggs held at constant 10, 15, and 20°C were estimated to require 635, 715, and 849 $DD_{7.39}$, respectively, to develop. Egg hatch rates were highest when held at a constant 15°C, though high rates were also obtained when eggs were held for 84 days at 10°C, then moved to 25°C. Almost all eggs enter diapause since very few eggs were able to hatch when moved to 25°C after 7 days of chill at either 5 or 10°C. Nymphal developmental rate increased with temperature from 15°C to 30°C for all instars, then declined again at higher temperatures. Nymphal survival was lower at 35°C than between 15-30°C for all instars, and first instars placed at 5, 10, and 40°C all died without molting. The lower developmental threshold was found to be 13.00±0.42°C for first instars, 12.43±2.09°C for second instars, 8.48 ± 2.99°C for third instars, and 6.29 ± 2.12°C for fourth instars. The DD requirement for nymphs in the previous instar to complete development to reach the second instar, third instar, fourth instar, and adult was 166.61, 208.75, 410.49, and 620.07 DD (base varied), respectively. These results provide key data to support laboratory-rearing efforts, the development of phenology models and help identify the potential range of SLF in North America. Other studies to evaluate the effects of heat waves and cold snaps on development are ongoing that will further define the phenology of this insect. The studies reported here have both been published (Keena and Nielsen 2021, Kreitman et al. 2021).

Keywords: phenology, hatch, development, survival, temperature

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Impact of biological control agents on Canadian emerald ash borer parasitoids

Chris J.K. MacQuarrie[a], Mary Gray[a], Gene Jones[a], and Tim Ladd[a]
[a] Natural Resources Canada, Canadian Forest Service, Sault Ste. Marie, ON, Canada

Three biological control agents have been released in Canada for the control of emerald ash borer. These species were released as part of the US-led effort to reduce the impact of the pest on ash trees in North America. The first releases of *Tetrastichus planipennisi* were made in 2013 with *Oobius agrili* and *Spathius galinae* following in 2015 and 2017. Beginning in 2018, we initiated experiments to examine the impact and dispersal of these parasitoids in the Canadian ash ecosystem. These experiments were intended to determine if the parasitoids were contributing to population regulation, and to determine if and how far the insect has spread. To examine the impact of the parasitoids on population dynamics we used a series of sequential caging studies to partition the attack of parasitoids on resident emerald ash borer in some of the oldest release sites. In our dispersal experiment, we used pan traps established at 2-30 Km from the oldest release sites to examine dispersal in southwestern Ontario, Canada. The results of these experiments will be used to estimate the contribution of these biological control agents to regulation of emerald ash borer in Canada.